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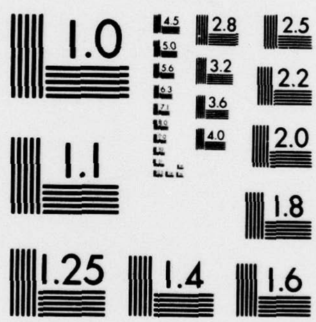

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AVSCOM Report No. 79-32

Production Engineering Measures Program
Manufacturing Methods and Technology

THE FABRICATION AND TESTING OF PROTOTYPE UH-1 AIRCRAFT WINDSHIELDS MANUFACTURED WITH A SHEET INTERLAYER

James O. Coast

Goodyear Aerospace Corporation
Arizona Division
Litchfield Park, Arizona 85340

August 1979

AMMRC TR 79-50

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Final Report

Contract Number DAAG46-78-C-0008

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Prepared for
U.S. ARMY AVIATION SYSTEMS COMMAND
St. Louis, Missouri 63166

ARMY MATERIALS AND MECHANICS RESEARCH CENTER
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This program was conducted to determine the feasibility of fabricating helicopter windshields with a designated urethane sheet interlayer. Four sets of full-size UH-1 windshields consisting of two each of two different constructions were fabricated and tested.

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FOREWORD

This is a final technical report on a program to build and test four sets of UH-1 helicopter windshields. The primary purpose was to demonstrate the feasibility of using a specified urethane interlayer in sheet form as the adhesive layer between the glass and plastic plies of the composite.

This project was accomplished as part of the US Army Aviation Research and Development Command's Manufacturing Technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army material. Comments are solicited on the potential utilization of the information contained herein as applied to present and/or future production programs. Such comments should be sent to: US Army Aviation Research and Development Command, ATTN: DRDAV-EXT, P.O. Box 209, St. Louis, MO 63166.

The program was conducted at Goodyear Aerospace Corporation, Arizona Division, Litchfield Park, Arizona, under Contract Number DAAG46-78-0008.

This work was done for the Army Materials and Mechanics Research Center, Watertown, Massachusetts.

The Technical Supervisor of this contract was Dr. Robert Sacher.

J.O. Coast is Project Engineer for Goodyear Aerospace. This report was submitted by the author in March 1979 for publication as a technical report. This report covers work conducted between April 1978 and February 1979.

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SUMMARY

This report describes the fabrication and testing of four sets of full-size UH-1 helicopter windshields, two each of two different constructions. The primary purpose was to demonstrate the feasibility of using a specified urethane interlayer in sheet form as the adhesive layer between the glass and plastic plies of the composites. A fabrication process was established which describes the step-by-step procedures used. Tests on the completed composites were conducted to determine their ability to withstand thermal stress while subjected to simulated in-flight loading.

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INTRODUCTION

1. GENERAL

The expanded mission requirements of helicopters have revealed many areas where improvement is needed. More specifically, the need for improvements in the helicopter transparencies has been identified and well documented. These improvements include increasing service life (abrasion resistance and environmental stamina); enhancing bird strike capability; defeating small arms projectiles and ordinance fragmentation threats; and the lowering of cost, all without any sacrifice in optical properties.

Helicopter windshields, almost without exception, are composed of a monolithic sheet of acrylic. This material is quite soft and is easily scratched by windshield wipers and cleaning, or abraded by soil debris thrown onto the surface by the rotary wing airflow. Spalling also occurs from larger items impacting the plastic, or from ballistic impact.

The best method of maintaining high levels of visibility, while improving scratch and impact resistance, and eliminating injurious spall particles is to incorporate glass/plastic composites. Recent advances in the state of the art have made such composites possible. High-performance glass/plastic composites have been developed which solve many of the problems mentioned. Scratching is reduced by the use of a glass outer ply, and spalling of injurious particles upon ballistic impact is eliminated by a polycarbonate inner ply. To reduce costs and extend service life of the glass/plastic composite, improved interlayer systems are desired.

2. PROGRAM SCOPE AND OBJECTIVES

This program consisted of an investigation of the advantages of fabricating full-scale UH-1 glass/plastic windshields using a polyurethane sheet interlayer, LRP-366, previously evaluated by the U.S. Army Material and Mechanics Research Center (AMMRC), Watertown, Massachusetts, and specified for this effort.

The objective of the program was to fabricate four sets of full-scale UH-1 windshields consisting of two sets each of two different constructions. These windshields were then to be evaluated optically and each construction subjected to thermal testing under load. As the result of the manufacturing and testing effort, a draft process description and manufacturing specification were then to be prepared for each type of composite fabricated.

SECTION II

TECHNICAL APPROACH

1. GENERAL

Contract DAAG46-78-C-0008 was initiated to demonstrate the feasibility of using E. I. DuPont's LRP-366 polyurethane as a sheet interlayer in the fabrication of full-scale aircraft glazings.

Two shipsets of UH-1 windshield panels of two different constructions (left hand and right hand) were fabricated to Bell Helicopter Part No. 204-030-666-44 contours and general edge band configurations.

2. DESIGN

The constructions were specified by AMMRC at the start of the program and are as follows:

<u>Type I</u>

0.085-in. Chemcor Glass No. 0401

0.030-in. DuPont polyurethane LRP-366

0.125-in. Lexan polycarbonate

<u>Type II</u>

0.250-in. Soda-lime annealed plate glass

0.060-in. Polyvinyl butyral adhesive

0.125-in. Soda-lime annealed plate glass

0.060-in. DuPont polyurethane adhesive LRP-366

0.125-in. Lexan polycarbonate.

The required configurations of the UH-1 windshields are as shown in Figure 1.

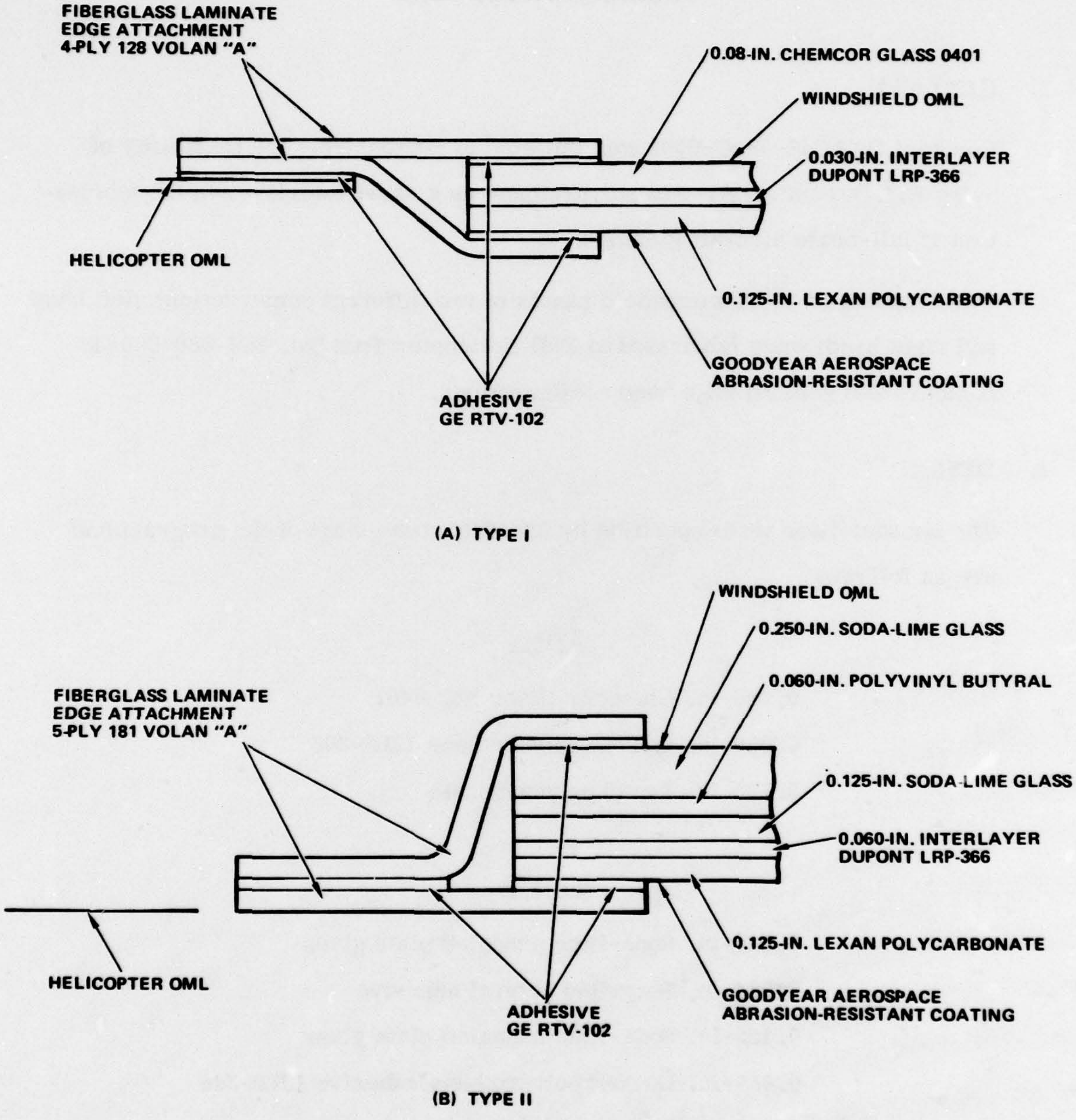

Figure 1. Prototype UH-1 Windshield Designs.

3. PROCESSING DEVELOPMENT

a. LRP-366 Development

Because no detailed processing of large, full-scale parts using the LRP-366 sheet interlayer existed, a development program was initiated to determine the character of the interlayer.

Early in the program, it was determined that extruded LRP-366 sheet was not available and could not be obtained in the limited quantities required for this program. This necessitated a process that could be used for producing sheet stock of adequate size and quantity to satisfy the requirements of this program.

Information regarding formulation and cure time and temperature was obtained from DuPont. With this data, Goodyear Aerospace proceeded by means of cup samples to establish the cure cycle as 16 to 20 hours at 190 ±10 deg F.

The first thin sheets attempted were open castings on flat plates. This method proved unsuccessful because the stock produced contained striations that did not disappear when the material was laminated. This problem was successfully overcome by casting between glass plates with separator film to release the urethane interlayer. This method produced a good-quality sheet of adequate size for the flat panel work. However, several attempts to increase the size to accommodate full-size prototype windshields were unsuccessful, primarily because of wrinkles in the separator film. These wrinkles transferred into the interlayer as sharp valleys and ridges which trapped air in final assembly. Further, when an attempt was made to splice two pieces of interlayer to make a panel, the flow of interlayer did not entirely erase the splice line. Additionally,

a difference in haze was visible when the pieces were positioned side by side in an assembly.

Because the cast sheets could not be spliced, and large sheets could not be satisfactorily cast, effort continued in this area until a method was developed in which billets of the LRP-366 were cast and cured. The billets were then pressed between platens on a hydraulic press to obtain the desired thickness and size. The press platen temperature was maintained at 260 deg F during pressing. When the proper thickness was reached, the platens were cooled to 140 deg F prior to removal of sheets.

Flat panels 30 × 36 in. were assembled using the pressed sheets of LRP-366 interlayer and were processed quite successfully. They were essentially air free and were of good optical quality. See Figure 2 for a photograph of a 30 × 36-in. Type I panel.

b. Polyvinyl Butyral Processing

Processing of polyvinyl butyral (PVB) has been well established for many years, so time, temperature, and processing pressure studies were not required. On curved composites such as the UH-1 windshields where contoured glass must be bonded to contoured glass with PVB under extreme pressure (200 psi), care must be taken to avoid glass breakage. Care must also be taken to assure a good match of contour, and careful adjustment of the temperature sequence relative to the application of pressure is necessary to minimize glass breakage.

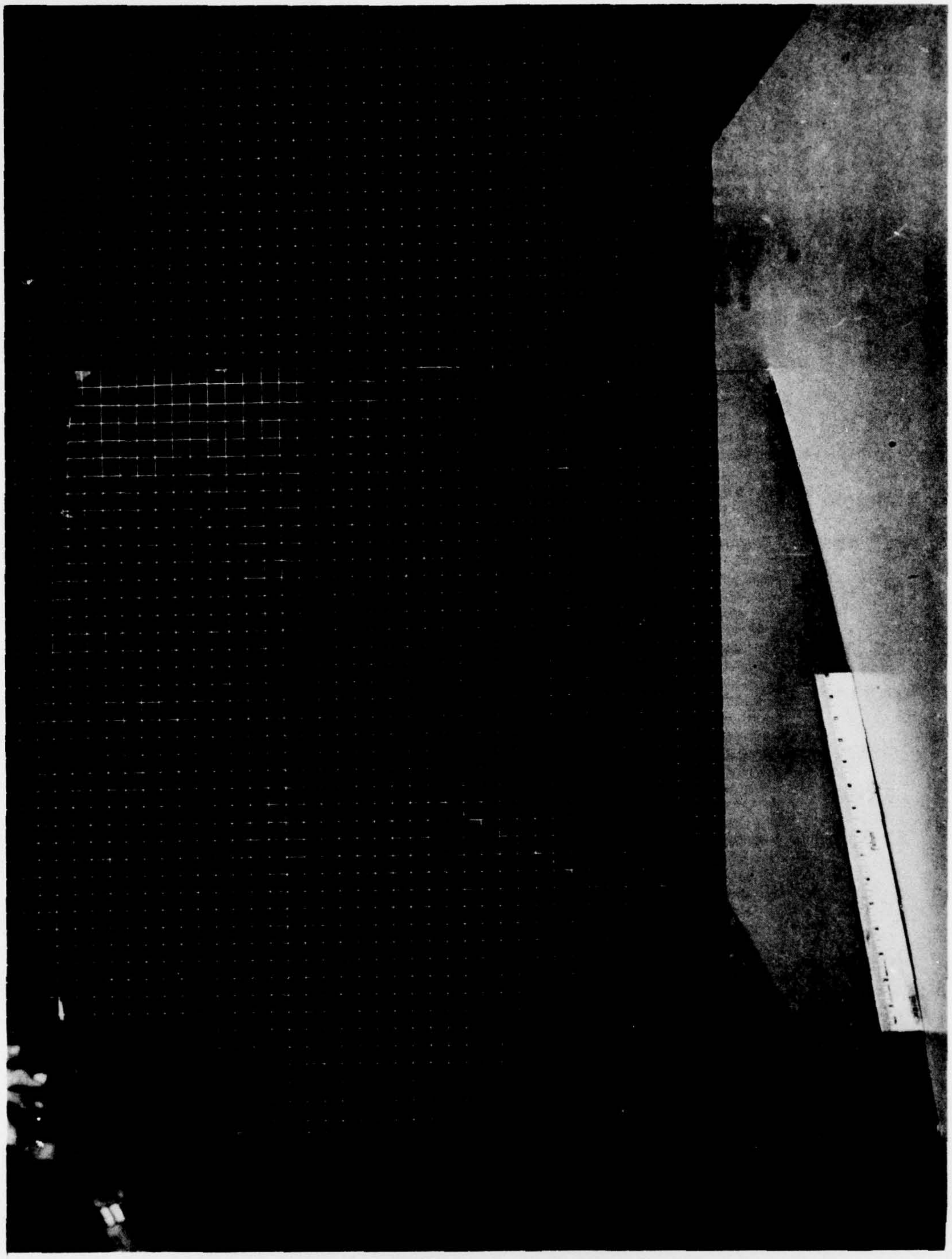

Figure 2. Flat Panel - Type I.

c. Interlayer Adhesion Studies

Good adhesion of an interlayer to the glass and plastic is required if in-service delamination is to be avoided. During the initial phase of this program, samples were made and tested to determine adhesion problems of LRP-366 interlayer to glass.

Ninety-degree peel samples (see Figure 3) were fabricated by casting the LRP-366 interlayer directly to the substrate. These samples were cut in one-inch strips as shown. The separator film allowed release of a three-inch tab. Utilizing a fixture as shown in Figure 3, the tab was clamped in the joint of a tensile test machine and the peel strength recorded. The sample tab was then pulled (see Figure 3) 90 deg to the test panel.

The following peel strength results represent samples made with cast-in-place LRP-366 interlayer:

Soda-lime glass/LRP-366	No primer	42-45 lb/in. width
Soda-lime glass/LRP-366	A-1100 silane primer*	50-53 lb/in. width
Soda-lime glass/LRP-366	A-1120 silane primer*	44-47 lb/in. width
Soda-lime glass/LRP-366	GAC 621 primer	43-45 lb/in. width .

*Product of Union Carbide.

These values indicated at first that adhesion to glass was no problem with or without a primer.

These tests were repeated utilizing LRP-366 sheet stock bonded to glass test plates by the autoclave process. The test results were:

Soda-lime glass/LRP-366	No primer	2 lb/in. width
Soda-lime glass/LRP-366	A-1100 silane primer	22 lb/in. width
Lexan polycarbonate/LRP-366	No primer	12 lb/in. width, minimum.

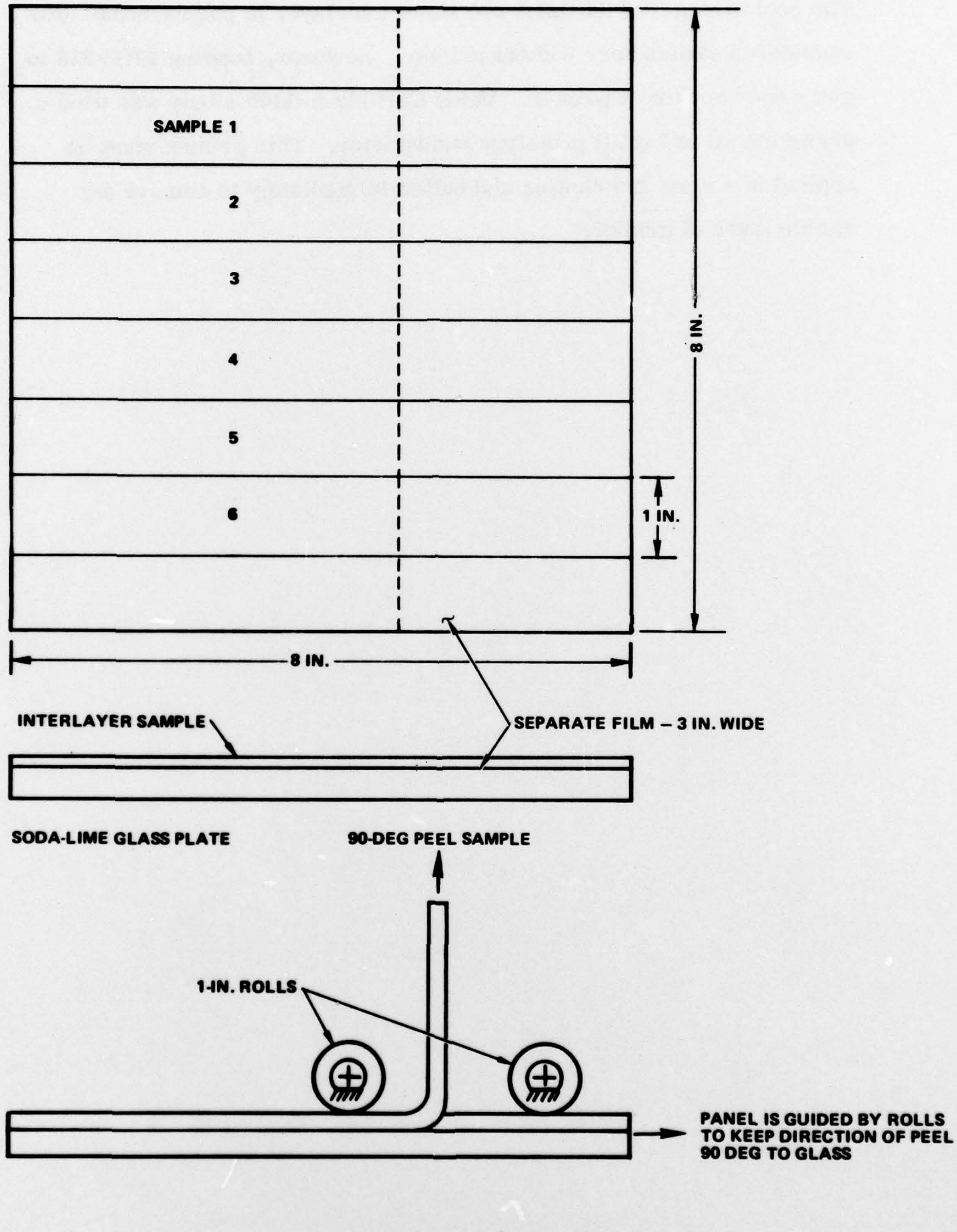

Figure 3. 90-Deg Peel Sample and Test Setup.

The peel strength of the LRP-366 sheet interlayer to polycarbonate was considered satisfactory without primer. However, bonding LRP-366 to glass does require a primer. Union Carbide A-1100 silane was used to prime the glass for all prototype windshields. This primer must be applied in a very thin coating and buffed immediately to remove any visible trace of primer.

SECTION III

FABRICATION OF PROTOTYPE

1. GENERAL

E. I. DuPont LRP-366 polyurethane interlayer in sheet form is thermoplastic and capable of bonding to glass and plastic substrates with proper application of heat and pressure. The process described in this report covers the procedures used to produce the Type I and II prototypes delivered to AMMRC.

2. SHEET INTERLAYER PROCESSING

Extruding the LRP-366 into sheet form is the ideal method to obtain uniform stock. For this method to be practical, however, a large quantity run must be manufactured to justify the setup cost. Because of the small amount of stock required for the four sets of UH-1 windshields fabricated in this program, it was not practical to consider extruded sheets.

To obtain sheet stock of quality comparable to that of extruded material, the following processing was used.

Batches of the LRP-366 polyurethane were mixed and degassed to remove all air from the mix. The liquid resin was poured into containers which produced cured billets of material 18 × 40 × 0.180 in. in size. The cure cycle was 190 deg F for 16 hr. The billets were wrapped and stored until needed. (Cleanliness is very important in this step because the tacky nature of the material causes it to pick up foreign matter.)

The final processing of the interlayer was accomplished by placing the billet on the heated platen of a hydraulic press and closing the press until the desired thickness was achieved. The press platen's temperature was set at 250 to

260 deg F at 50 psi pressure. The press platens were cooled before removal of the finished sheets. The interlayer sheets thus produced were of high quality.

3. WINDSHIELD ASSEMBLY

The windshield was assembled as follows:

a. The windshield glass (soda-lime or Chemcor) was cleaned and primed with A-1100 silane primer.

b. The polycarbonate inner ply was trimmed to size and formed to the contour of the glass ply it must match.

c. The interlayer sheet was positioned on the glass.

d. The polycarbonate was placed over the interlayer sheet and glass ply.

e. A formed caul sheet was then placed over the polycarbonate ply. This aided in maintaining the uniform thickness of the interlayer by preventing localized pressure buildups which can cause uneven interlayer flow when under pressure and bulging of the polycarbonate.

f. The entire assembly was then sealed in a vacuum bag and placed in an autoclave, where it was subjected to 100 psi pressure and a temperature of 230 deg F for 3 hr.

g. The assembly was cooled under pressure until the interlayer stabilized.

h. The part was inspected to verify that it was free of air inclusions and that it was of uniform thickness adequate to produce an optically acceptable part.

i. The windshield assemblies were then completed by bonding fiberglass-reinforced plastic edge attachments to the composites with a silicone adhesive.

4. PROCESSING PROBLEMS ENCOUNTERED

Air entrapment was much more pronounced on curved panels than on flat pieces of equal size, probably because some mismatch of the various plies allowed some pockets where air accumulates and cannot be forced from the assembly. Because of the extreme softness of the LRP-366 interlayer at laminating temperature, the edges of the assembly pinch together, making it difficult for the air to be removed. To minimize this effect, a fiberglass tape was placed around the periphery of the part extending approximately 3/8 in. into the assembly. This tape acts as a bleeder and allows more air to escape when the pressure is applied. The result was a reduction in the amount of air remaining in the part, but not complete elimination of air inclusions.

Glass breakage was a problem both with the soda-lime glass and the Chemcor glass. The breakage with the soda-lime glass, as mentioned previously, was somewhat controlled by exercising care when forming and by adjusting the temperature pressure sequence of the PVB bonding operation to allow the PVB to soften before application of pressure.

The breakage of Chemcor glass was not associated with a particular operation, but rather seems to be a result of building stresses into the part because of contour mismatch. Thus, the Chemcor glass would break with an application of load that would not normally be considered critical.

SECTION IV

TESTING

1. LOW-TEMPERATURE TESTING OF FLAT PANELS

The coefficient of thermal expansion of the polycarbonate portion of this composite is greater than seven times that of the soda-lime glass. The great difference in expansion characteristics between these two materials results in shear stress in the interlayer.

The shear stress from low-temperature exposure is reacted with a compression load at the center of the glass face and a tensile load in the polycarbonate back ply. These two axial reactions create a couple that is reacted in bending on the composite. This bending generates outside fiber tensile stresses in the glass that are superimposed onto the compressive axial stress. At extreme temperature, the tensile component from the bending stress can exceed the compressive stress from the axial reaction by enough to exceed the tensile strength of the glass.

The contract statement of work specifies the prototype unit to be temperature cycled in accordance with USAS Z 26.1. This cycle is as follows:

a. Place specimen in air at a temperature of -54 ±5 deg C (-65.2 ±9 deg F) for 6 hr.

b. Place specimen in still air at +23 ±1.1 deg C (+73.4 ±2 deg F) for 1 hr or until specimen attains temperature equilibrium

c. Place specimen in circulating air at +72 ±2.2 deg C (+161.6 ±4 deg F) for 3 hr.

d. After removal to still air at 21 to 22 deg C (69.8 to 80.6 deg F) and cooling at this temperature, examine the specimen.

The Type II construction was considered to be the more critical construction at the low temperature. For this reason, a 30 × 36-in. panel of the Type II construction was selected for exposure to the aforementioned temperature cycle.

Because it was anticipated that the test panel would not withstand -65 deg F temperature exposure, it was decided to expose the panel to -40 deg F and to perform an interim examination. The panel was exposed to -40 deg F for 2 hr and then allowed to stabilize at 75 to 80 deg F for approximately 2 hr. There was no evidence of delamination, cracking, or other signs of deterioration.

The test chamber was then lowered to -65 deg F and the panel positioned in the chamber. The temperature recorder read -50 deg F immediately after the chamber door was closed. As viewed through a window, a large crack appeared in the glass within six minutes after the chamber door was closed. The temperature of the chamber was recorded at -55 deg F (see Figure 4).

As a result of the described low-temperature test, the statement of work was revised to change the -65.2 deg F cold temperature test requirement to -20 ±5 deg F, and two additional panels were tested. Both panels (Types I and II) were exposed to the -20 deg F temperature with no glass breakage or delamination.

2. OPTICAL EVALUATION

All windshields were checked as follows:

a. Light transmission per Federal Test Method 406, Method 3022.

b. Haze per Federal Test Method 406, Method 3022.

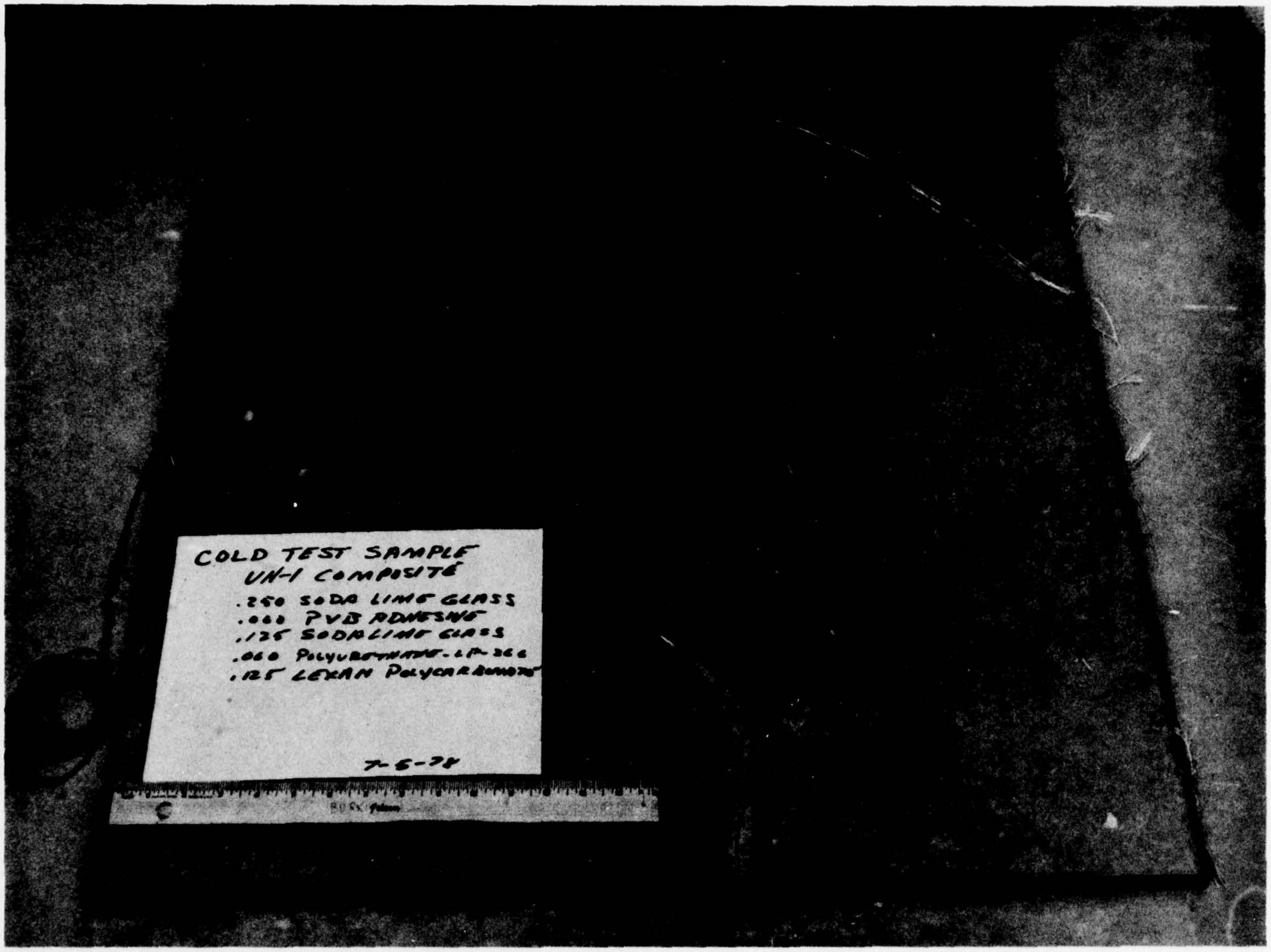

Figure 4. Cold Test Panel - Type II.

c. Optical deviation readings were made by viewing an annular target with a telescope through and normal to the test article. The deviation was taken by measuring the location of the target relative to telescope crosshairs and was recorded as minutes of arc.

d. Optical distortion per MIL-G-5485C, paragraph 4.5.3.

e. Thickness measurements in inches.

Figure 5 is included to show the points at which prototype windshields were checked for thickness and deviation. Light transmission and haze readings were taken and reported for points 4, 5, and 6 on each windshield. The deviation and thickness were averaged and the high, low, and average values recorded (see Table 1).

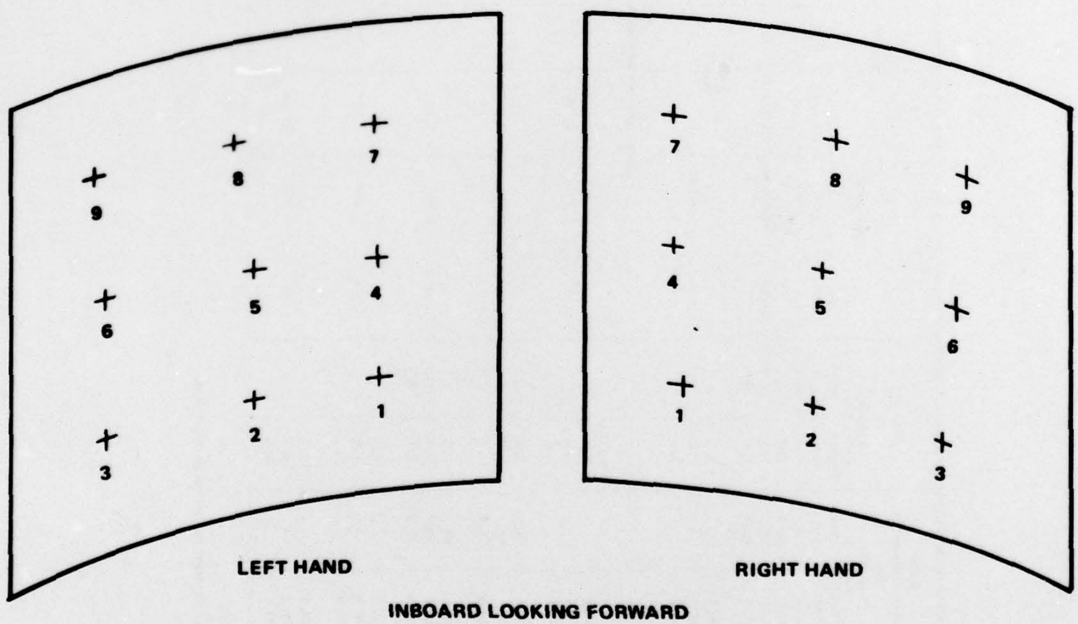

Figure 5. Layout of Points for Optical Evaluation.

TABLE 1. RESULTS OF EVALUATION OF PROTOTYPE WINDSHIELD BEFORE AND AFTER PROTOTYPE THERMAL TEST

Type construction designation	Light transmission (%) (at 3 points)		Haze (%) (at 3 points)		Thickness (in.)			Optical deviation in minutes of arc						Distortion from measuring photos	
								Before test			After test				
	Before test	After test	Before test	After test	High	Low	Average	High	Low	Average	High	Low	Average	Slope	Remarks
Type I, LH, S/N 1*	86.6 86.7 86.7	85.4 85.5 85.4	1.6 1.1 1.1	2.1 1.7 2.0	0.280	0.268	0.273	5	1.5	2.9	5	1	2.9	1-7	Distortion caused by bulge in backup tool
Type I,** RH, S/N 1*	86.3 85.6 84.7	-	2.1 2.3 3.6	-		No reading		4	2	2.7				1 in 12	Edge distortion caused by excessive flow of interlayer at edge
Type I, LH, S/N 2					Broke assembling edge attachments - no evaluation										
Type I, RH, S/N 2	85.3 85.6 85.6	-	2.4 2.2 2.3	-	0.273	0.247	0.260	7	1	3.3	-	-	-	1-10	Edge distortion caused by excessive flow of interlayer at edge
Type II, LH, S/N 1*	79.0 78.9 78.9	78.5 78.1 78.2	1.6 1.7 1.7	2.4 2.4 2.4	0.616	0.595	0.605	7	2	5	7	3	5.3	1 in 9	Edge distortion caused by excessive flow of interlayer at edge
Type II, RH, S/N 1*	80.5 80.6 80.5	80.7 80.2 80.2	1.5 1.5 2.1	2.0 2.0 2.1	0.623	0.607	0.617	6	2	4	6	2	4.1	1 in 10	Distortions very minor
Type II, LH, S/N 2	78.9 78.8 78.8	-	1.9 1.9 2.2	-	0.614	0.605	0.610	6	1	2.9	-	-	-	1-7	Distortion caused by backup tool
Type II, RH, S/N 2	80.0 80.3 79.7	-	3.3 3.1 3.4	-	0.640	0.627	0.634	7	2	4.6	-	-	-	1 in 9	

*Designated test unit.

**Part broke drawing vacuum; no evaluation after test.

Distortion readings included in Table 1 were made from photographs (Figures 6 through 12) and were measured where the highest slope lines were noted. Readings did not include a band approximately four inches around the periphery. The distortion that is obvious in this area is attributed to the pinchoff discussed previously.

The two distortion areas that can be seen in Figures 6 and 11 for Type I, S/N 1 (left hand) and Type II, S/N 2 (left hand) windshields were traced to the backup plate. Two irregular areas in the backup caul sheet were found that coincided with the distortion in the photographs.

The haze and light transmission values shown are well within the expected limits for composites of this type. The variation in haze readings correlates with thickness changes in the LRP-366 interlayer.

3. THERMAL TESTING - PROTOTYPE

a. Test Requirement

The contract required that one each left-hand and right-hand windshield of Type I and Type II configuration be thermally tested while mounted to a fixture and pressurized to simulate loads incurred on the helicopter at a top airspeed of 120 knots.

The part was subjected to -28.9 ±1.1 deg C (-20 ±2 deg F) for 6 hours, then placed in still air at 23 ±1.1 deg C (73.4 ±2 deg F) for 1 hour to permit temperature equilibrium to be attained in the specimen. The windshield was then subjected to 72 ±2.2 deg C (161.6 ±11 deg F) for 3 hours. The part was cooled to 20 to 27 deg C (69.8 to 80.6 deg F) and allowed to stabilize at ambient temperature.

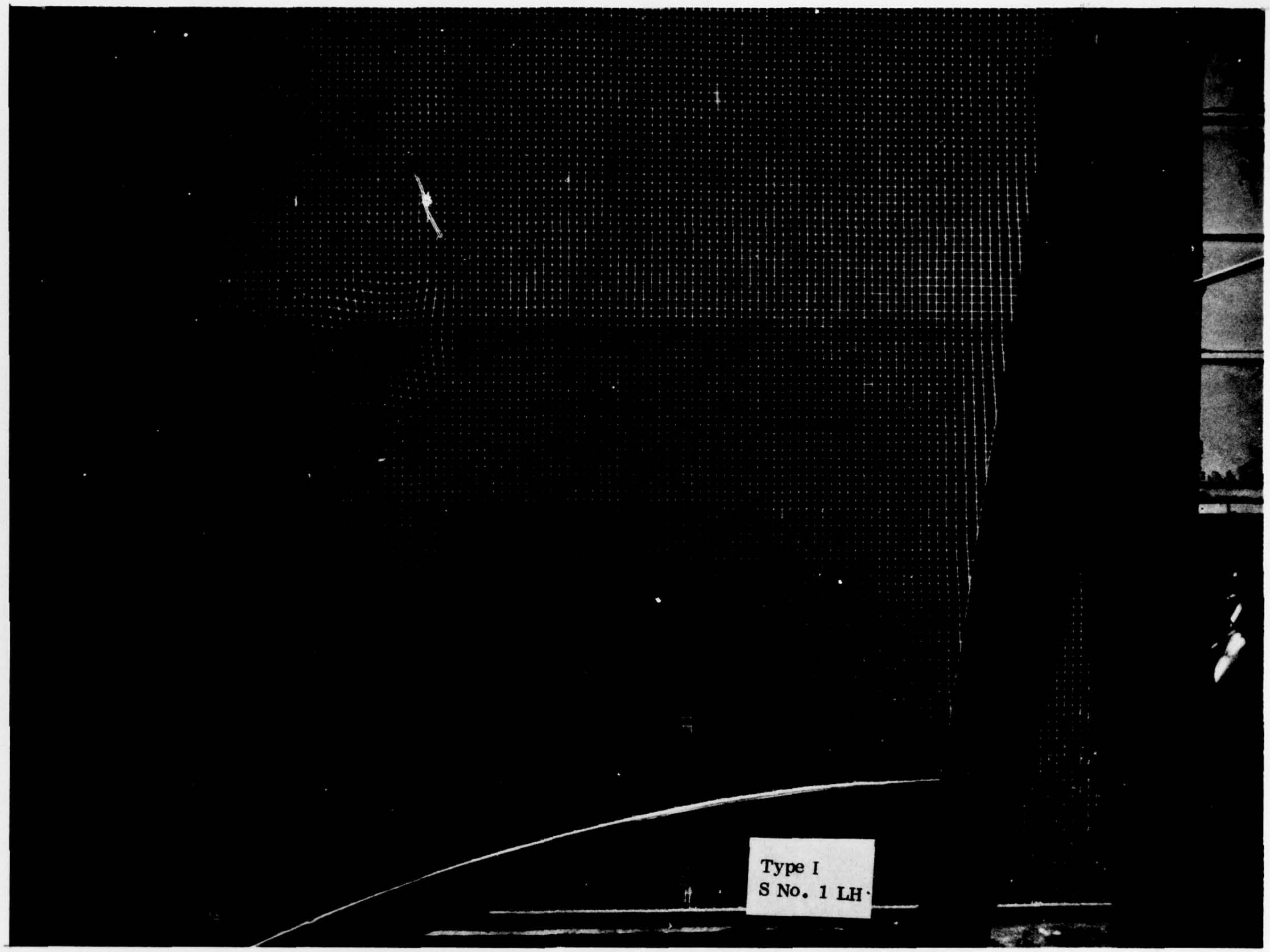

Figure 6. Gridboard Photograph - Type I, S/N 1 (Left Hand).

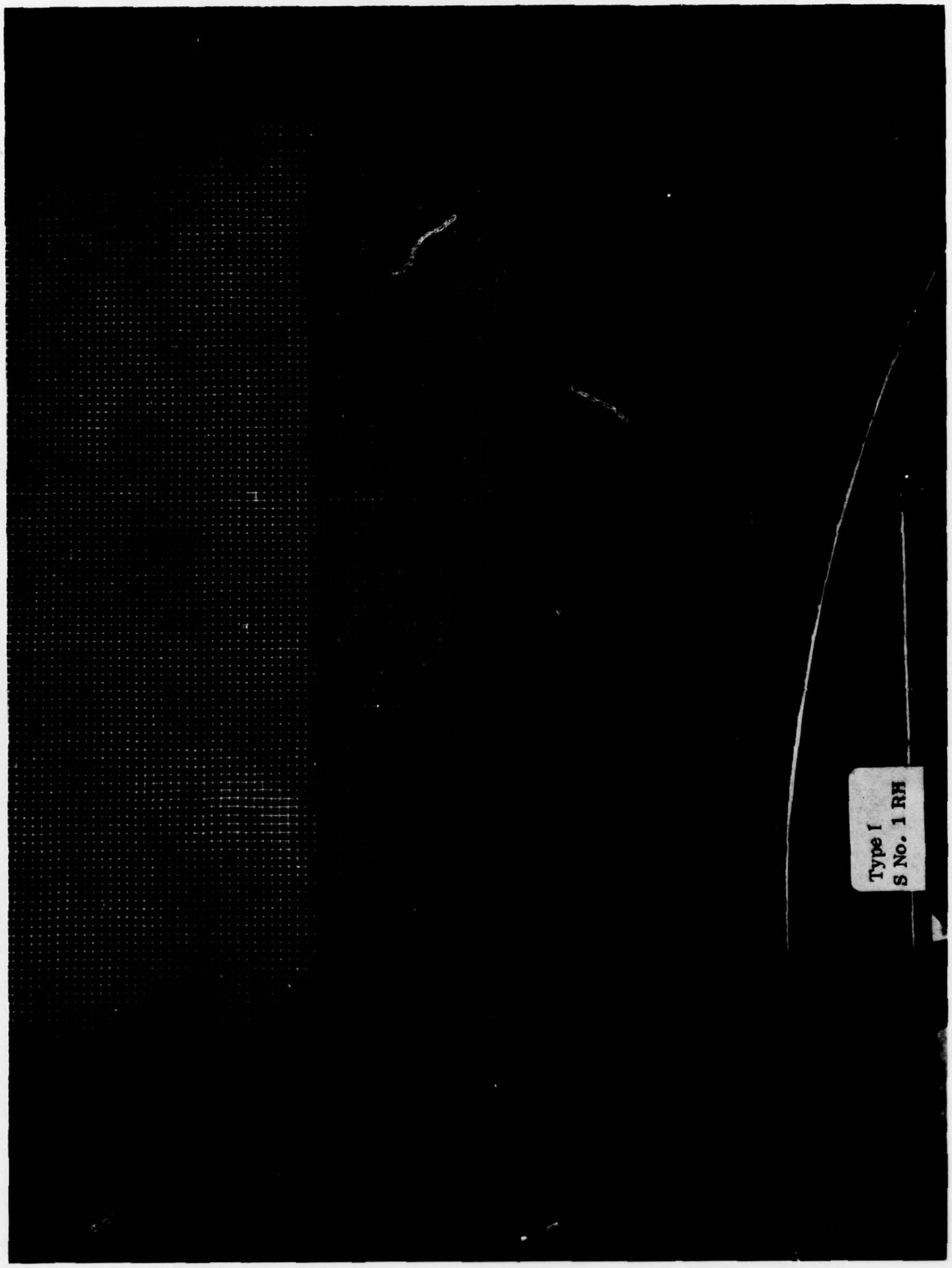

Figure 7. Gridboard Photograph - Type I, S/N 1 (Right Hand).

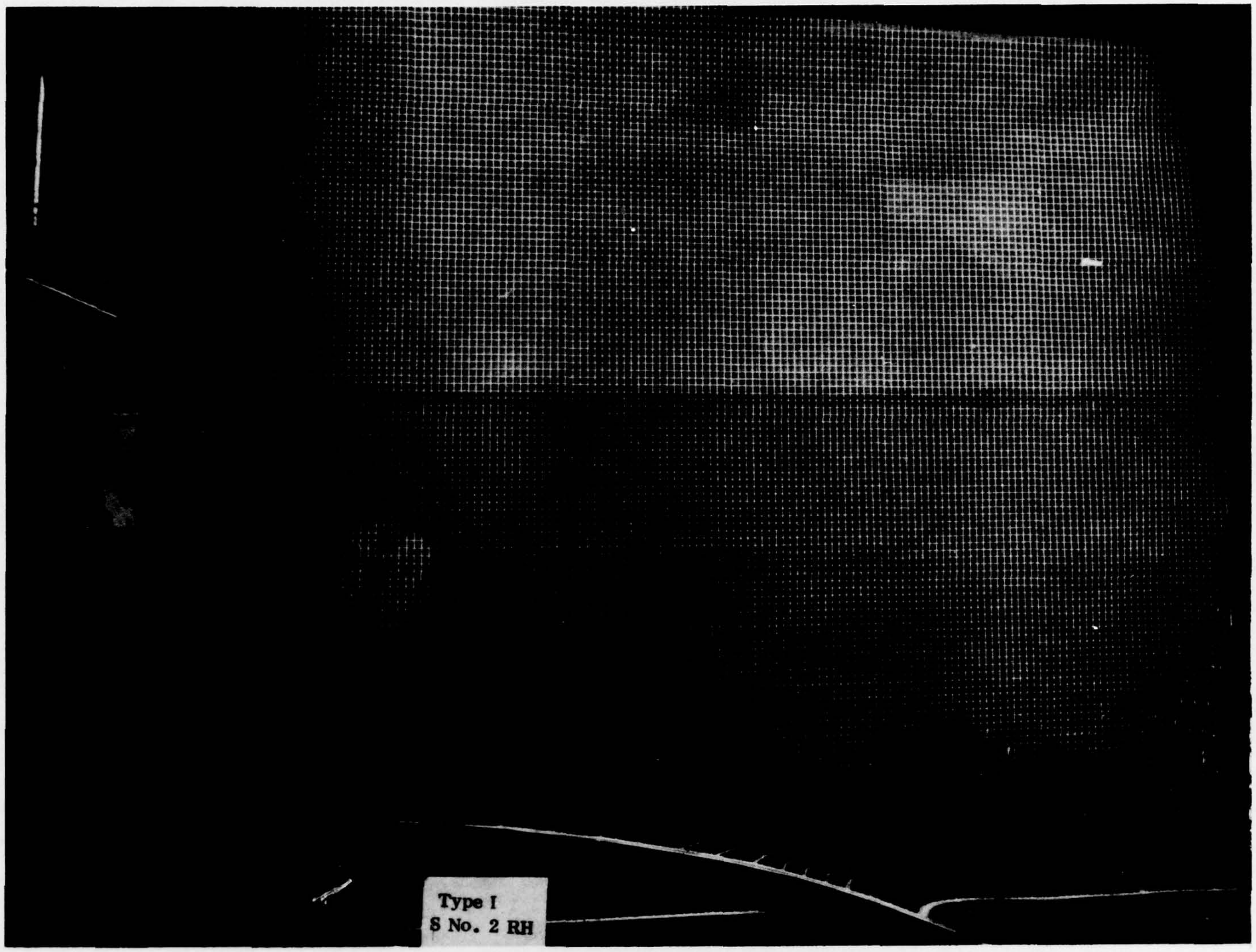

Figure 8. Gridboard Photograph - Type I, S/N 2 (Right Hand).

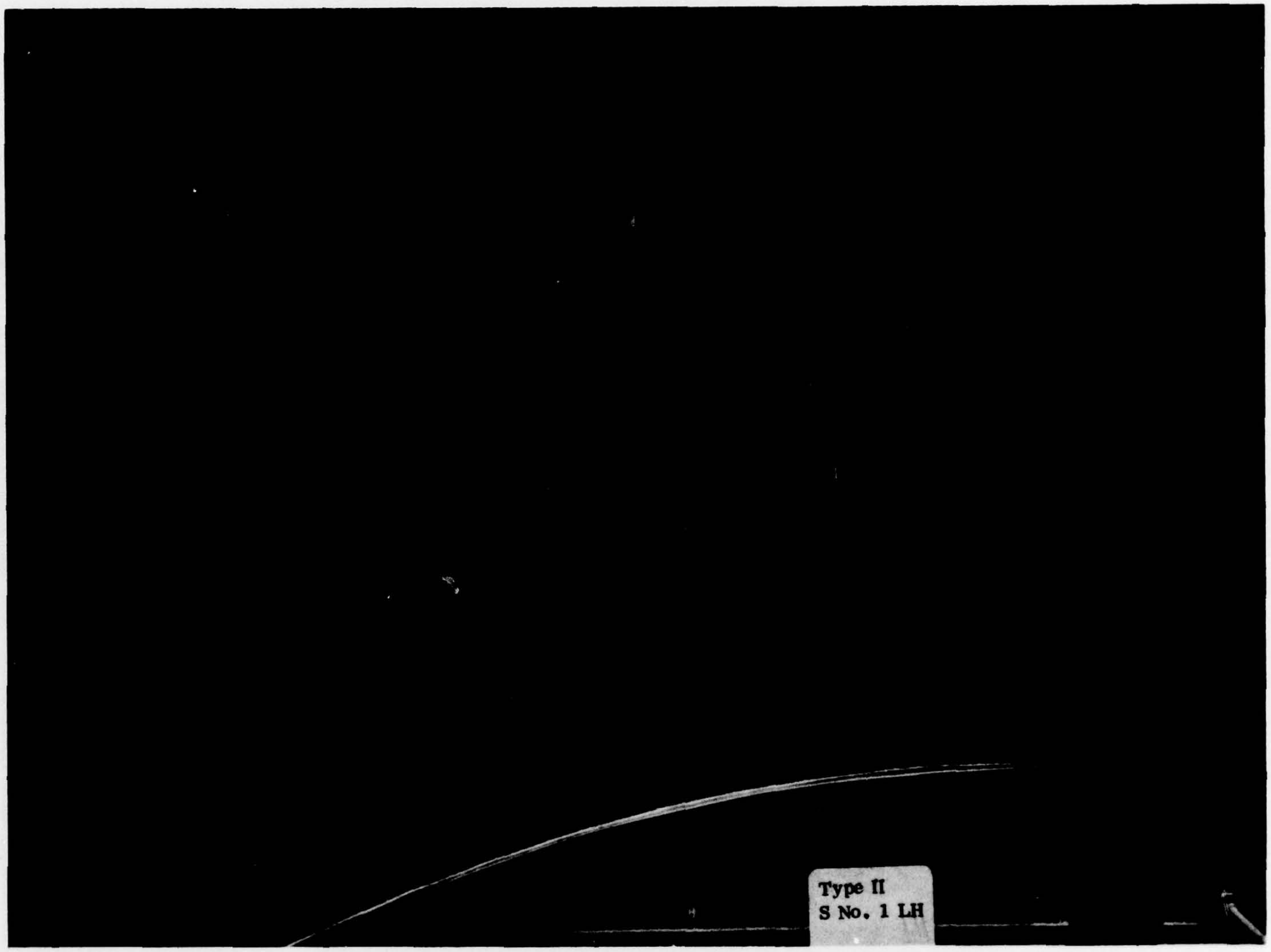

Figure 9. Gridboard Photograph - Type II, S/N 1 (Left Hand).

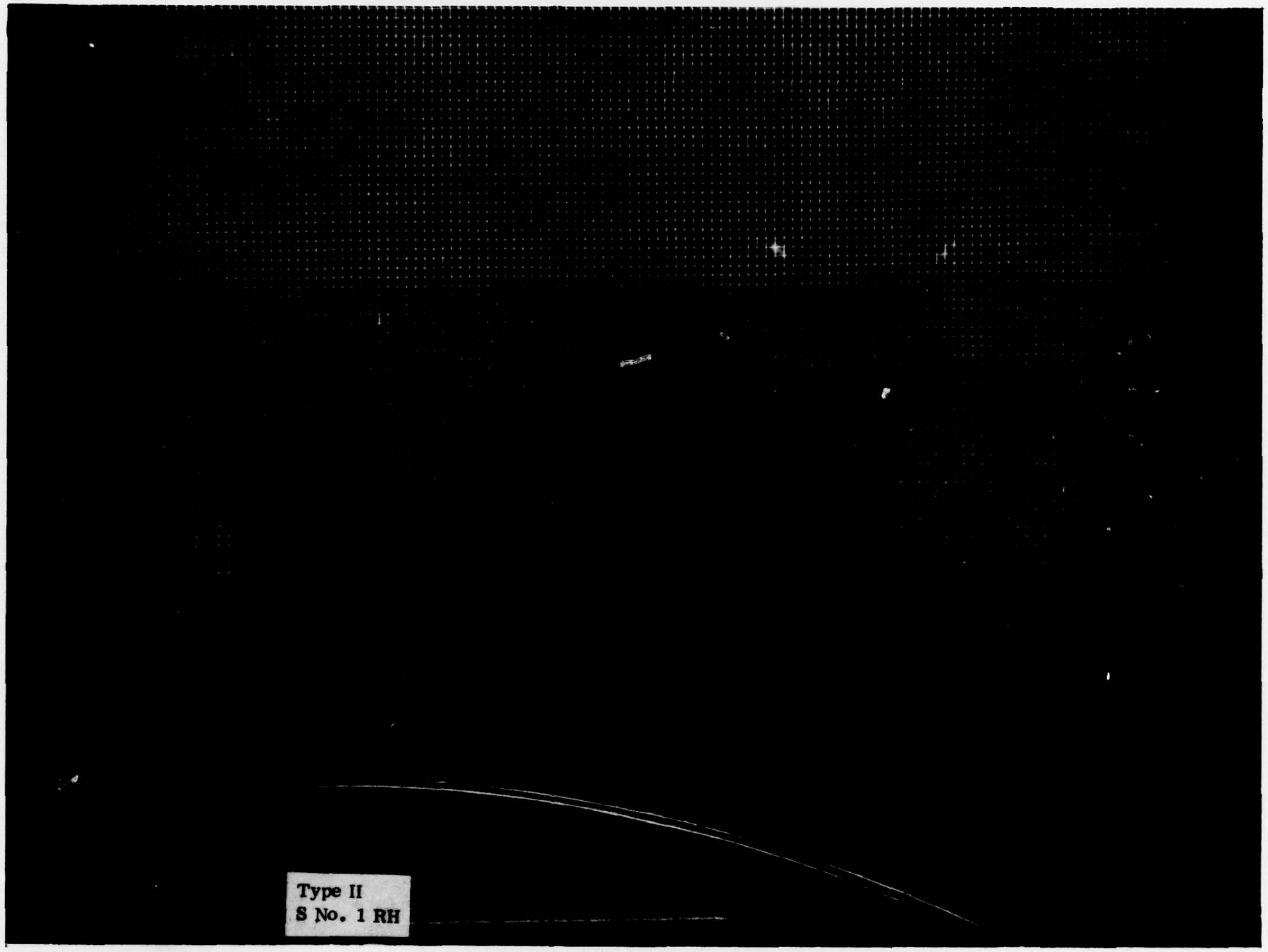

Figure 10. Gridboard Photograph - Type II, S/N 1 (Right Hand).

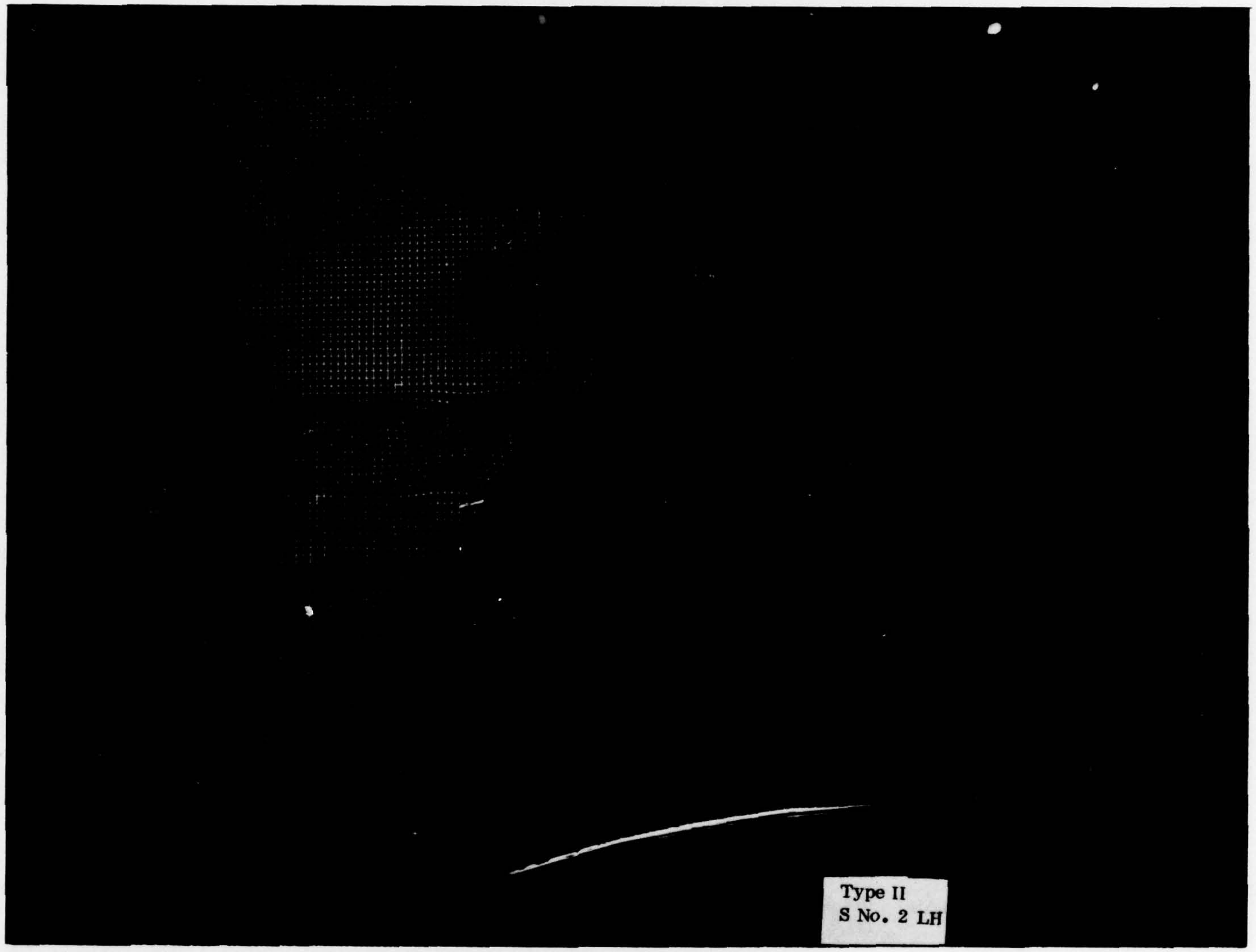

Figure 11. Gridboard Photograph - Type II, S/N 2 (Left Hand).

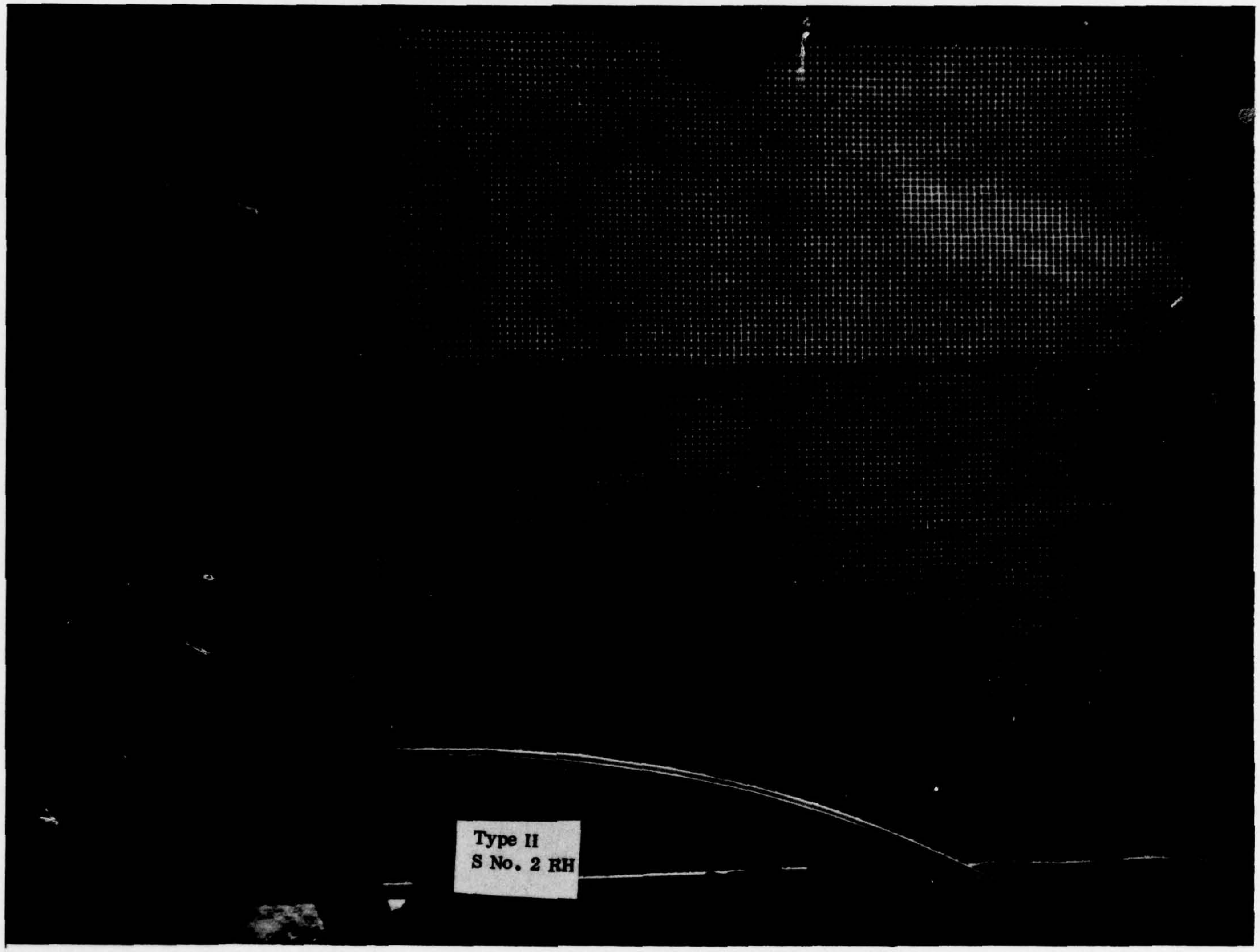

Figure 12. Gridboard Photograph - Type II, S/N 2 (Right Hand).

b. Test Fixture and Procedure Description

One test fixture for each hand was fabricated to duplicate the UH-1 structural shape at the windshield inner face. The part was mounted as shown in Figure 13. The fixture was constructed to provide a sealed chamber, allowing a vacuum to be applied to the aft side of a windshield to simulate aerodynamic loading imposed by the helicopter at an airspeed of 120 knots. The calculated loading for the windshield at 120 knots is 0.33 psi minimum.

Vacuum was applied to the test fixture by a vacuum pump connected with a bleeder valve to control the pressure differential between the inside and outside of the fixture. This differential was monitored by a differential manometer that measures in inches of water. The temperature cycling was performed in a temperature chamber of sufficient size to cycle both left-hand and right-hand fixtures from the low to high end of temperature cycle (see Figure 14).

Designations of equipment used are as follows:

Vacuum pump	Seargeant/Welch Scientific Model 1399
Differential manometer	King Engineering Model BUC 36
Temperature chamber	Thermotron Chamber Model W-512 .

The 0.33-psi simulated load required is equivalent to 9.12 in. of H_2O. To prevent the load on the windshield from dropping below 0.33 psi, a pressure differential of 10 in. of H_2O (minimum) was maintained throughout test.

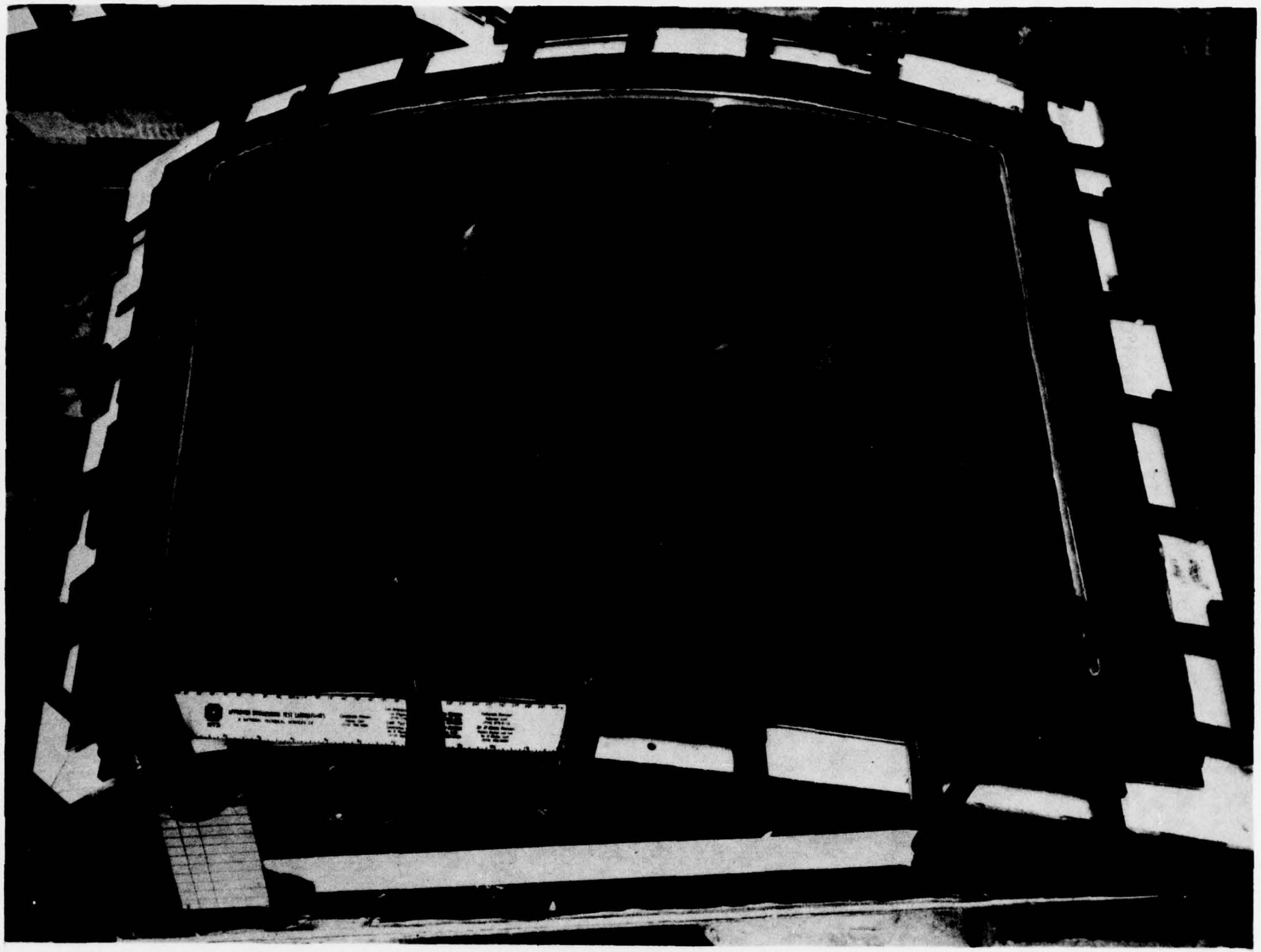

Figure 13. Test Fixture with Type II Windshield Mounted.

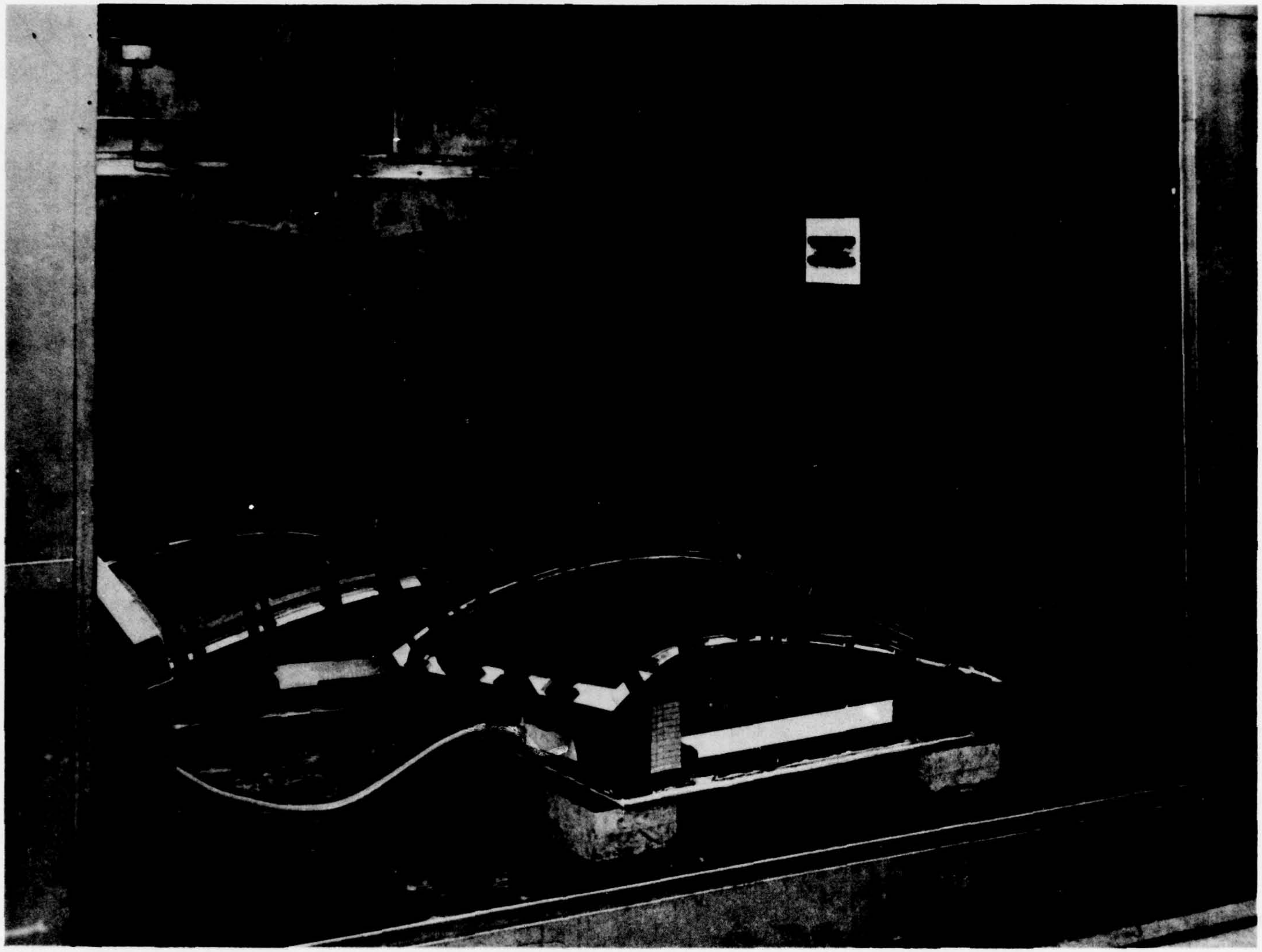

Figure 14. Test Chamber with Left-Hand and Right-Hand Test Fixtures.

c. Test Results

The designated test assemblies were:

Type I, S/N 1, left hand

Type I, S/N 1, right hand

Type II, S/N 1, right hand

Type II, S/N 1, right hand.

One test article, Type I, S/N 1, right hand, was mounted on the fixture as discussed, and vacuum was drawn to check for leaks. Before a 0.25-psi pressure differential was attained, the Chemcor glass was broken. No further testing action was taken. This test article is shown in Figure 15 mounted in the fixture.

The remaining test articles were subjected to the thermal test at pressure as described. All units were examined visually after the low temperature cycle and again after the elevated segment of the temperature cycle. The visual examination of subject units showed no evidence of cracking, clouding, or delamination. The test units were checked again for light transmission and haze, deviation, and distortion.

Table 1 shows results after thermal testing. The test data shows no real change except in haze. The percentage of haze generally shows approximately a one-half of one percent increase in haze level. The change is not great but is consistent.

There was no measurable change in distortion (see Figures 16, 17, and 18). There were some differences noted in the deviation measurements before and after test. These differences are random and do not fit a pattern. The differences noted are considered to be testing variations.

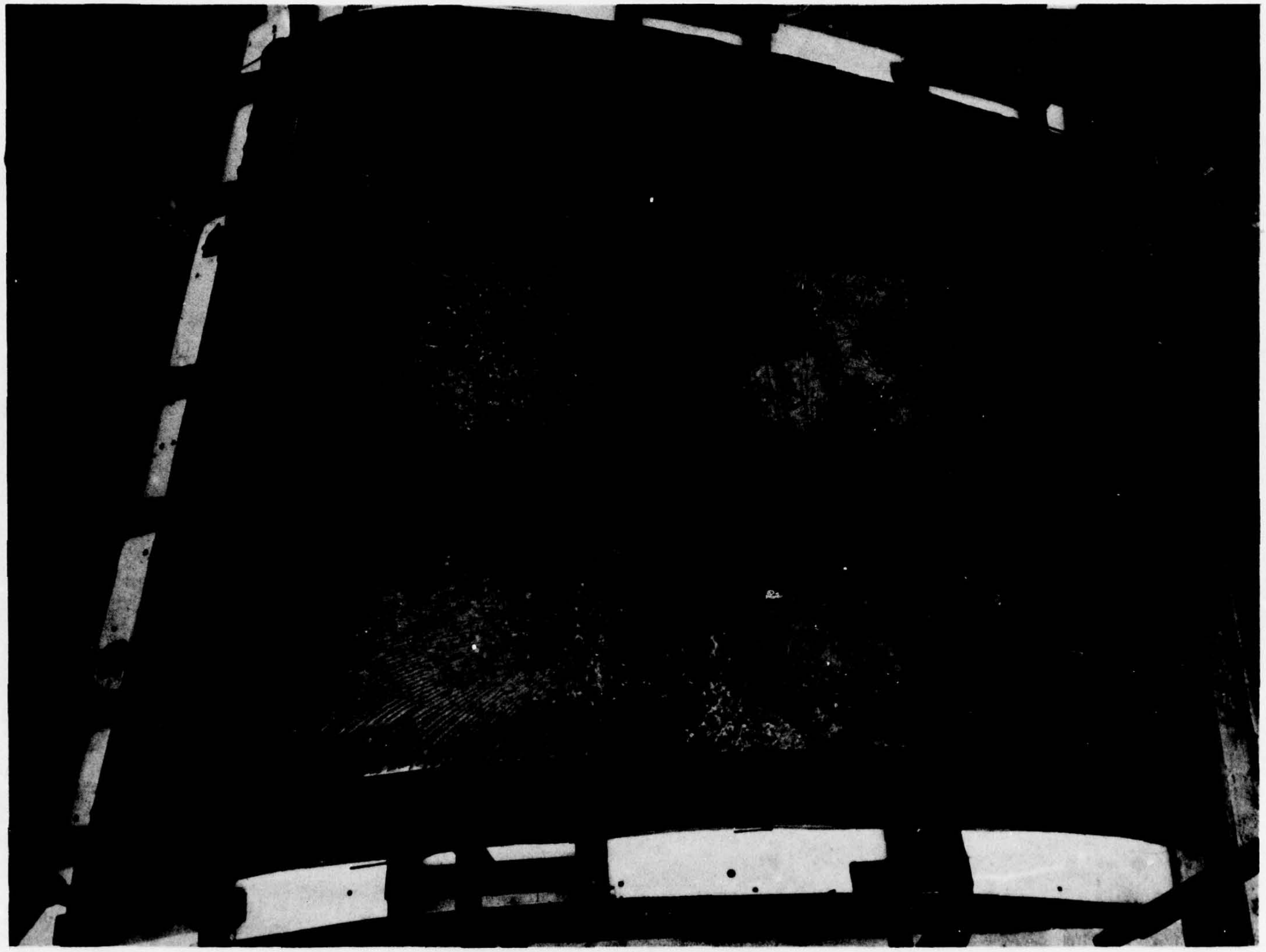

Figure 15. Type I, S/N 1 Left-Hand Windshield after Failure at Vacuum Test Check.

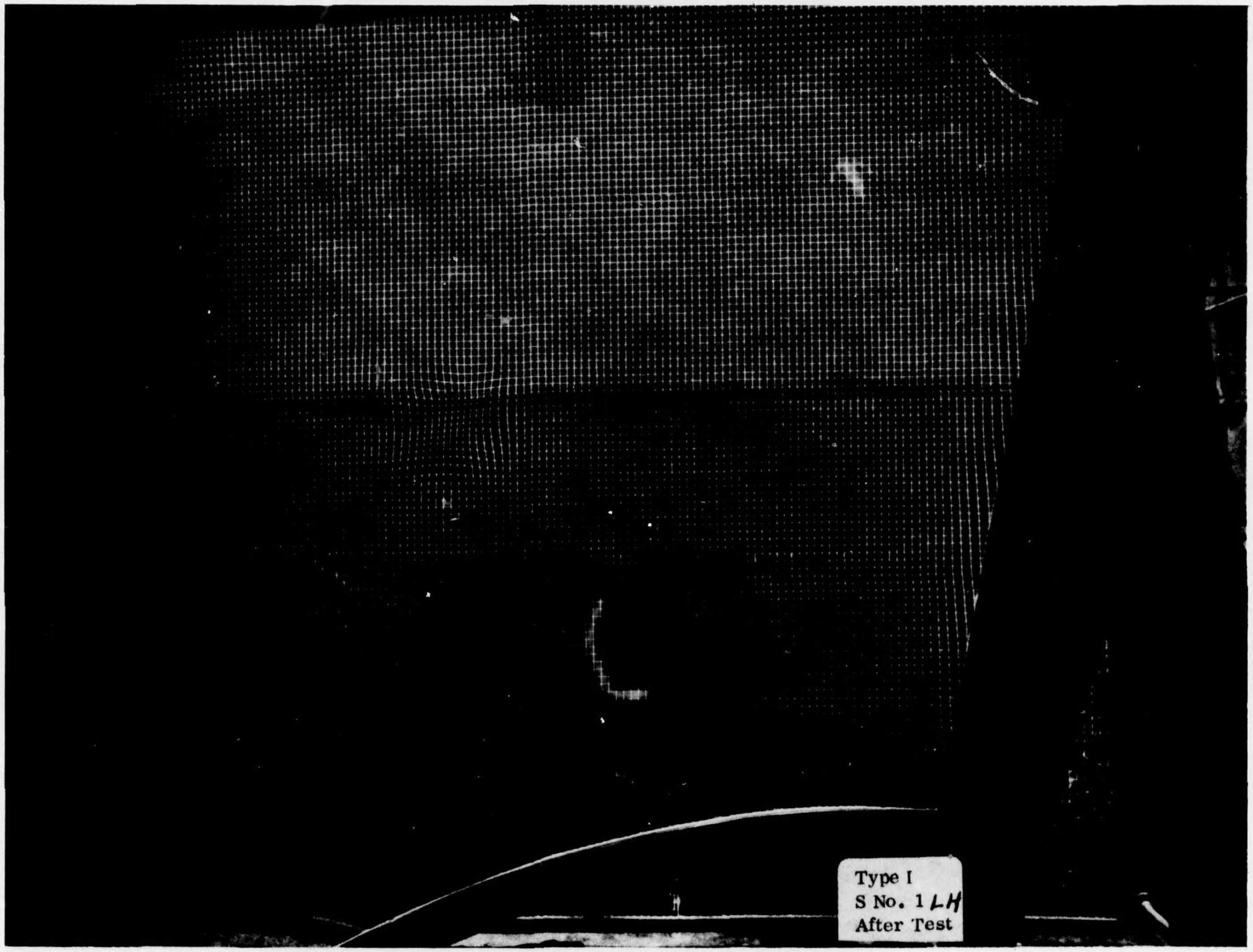

Figure 16. Gridboard Photograph - Type I, S/N 1 (Left Hand, after Test).

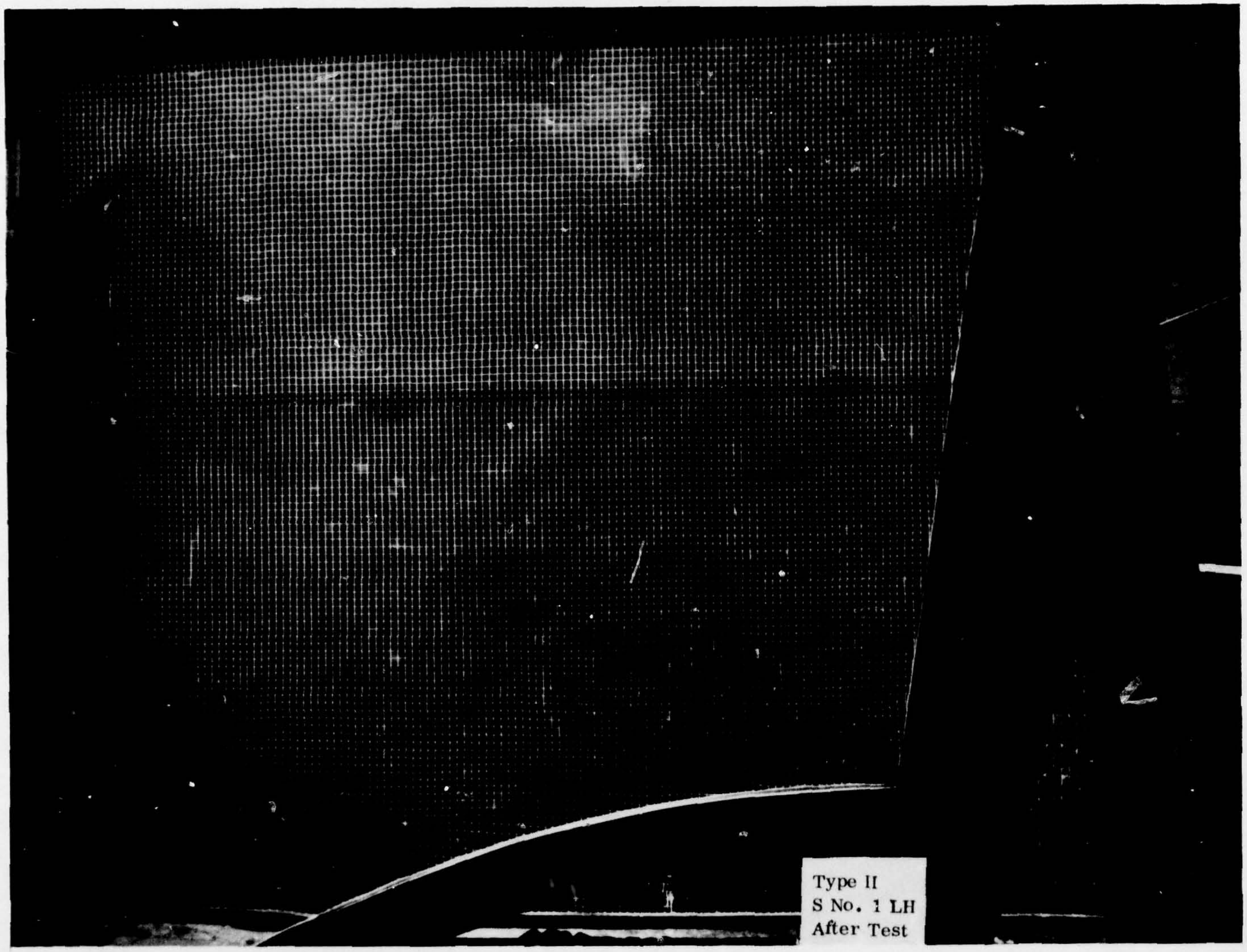

Figure 17. Gridboard Photograph - Type II, S/N 1 (Left Hand, after Test).

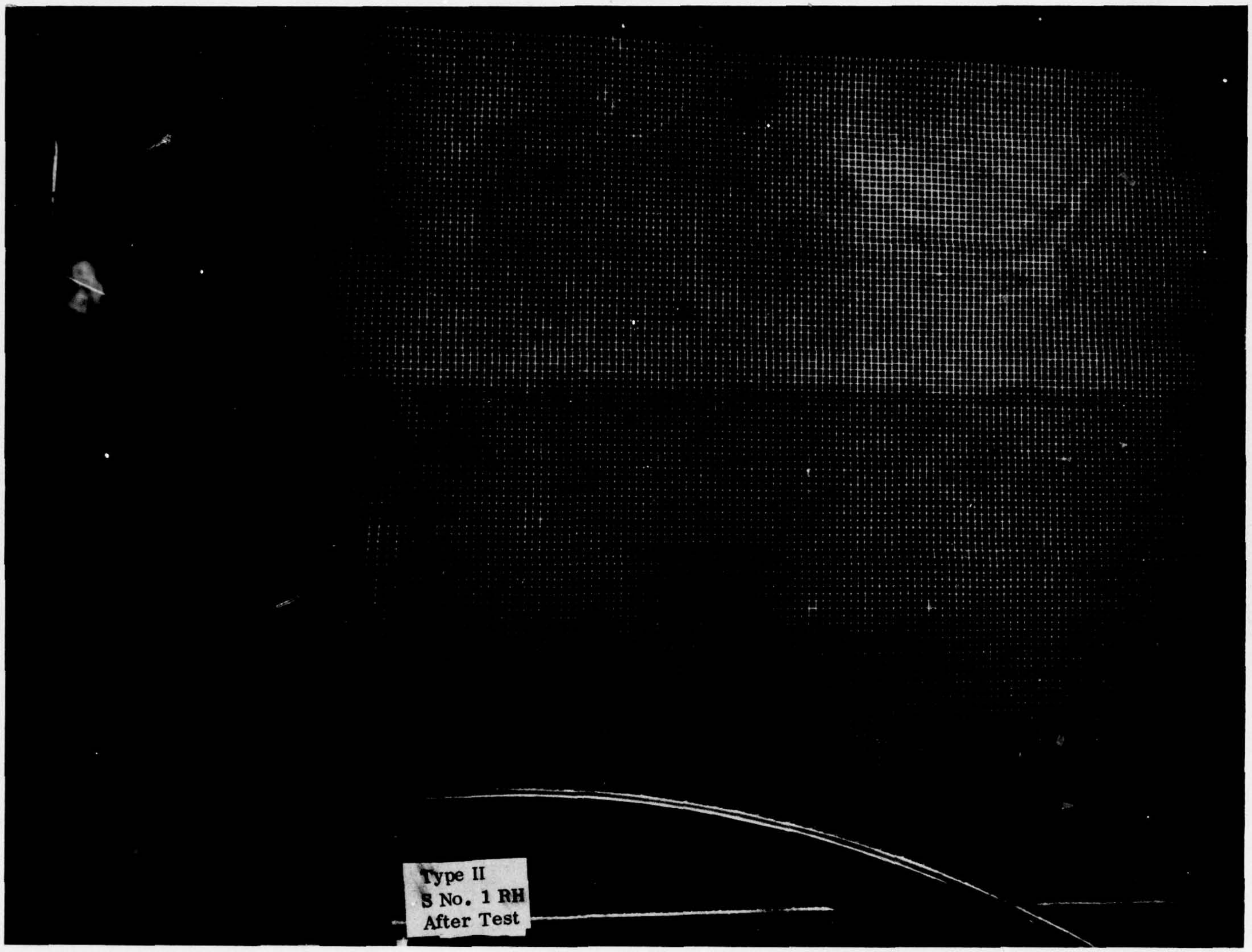

Figure 18. Gridboard Photograph - Type II, S/N 1 (Right Hand, after Test).

SECTION V

CONCLUSIONS

The conclusions resulting from the work effort performed on this contract are as follows:

1. The LRP-366 interlayer has good optical clarity and is well within all requirements (light transmission and haze) required for glass/plastic composites.

2. The adhesive bond achieved with glass and polycarbonate seems to be adequate to withstand repeated thermal cycling.

3. Based on the limited prototype work performed, it is believed UH-1 windshields of glass/plastic constructions can be fabricated successfully if:

    a. The sheet interlayer can be obtained in extruded sheets of uniform thickness

    b. The flow characteristics of the interlayer can be improved either by altering the resin formulation or by developing a temperature-pressure cycle more compatible with the interlayer.

4. Constructions utilizing Chemcor glass exhibit a greater tendency to crack during lamination because of the difficulty of obtaining the good contour match between the various plies of the composite.

APPENDIX A

PROCESS DESCRIPTION AND SPECIFICATION FOR MANUFACTURING GLASS/PLASTIC COMPOSITES USING POLYURETHANE LRP-366 INTERLAYER

ABSTRACT

This document establishes and describes the procedure and controls for the manufacture of UH-1 windshields of glass/ polycarbonate composite utilizing a polyurethane sheet interlayer.

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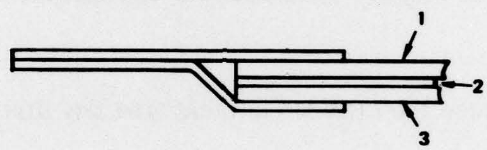
TABLE OF CONTENTS

PROCESS DESCRIPTION AND SPECIFICATION FOR MANUFACTURING GLASS/PLASTIC COMPOSITES USING POLYURETHANE LRP-366 INTERLAYER

1. SCOPE

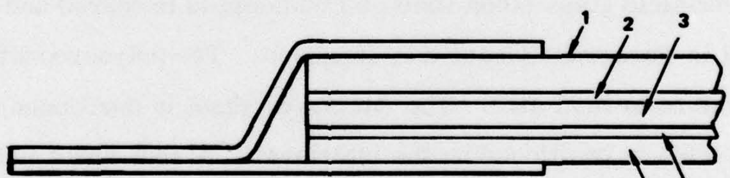
1.1 Scope. - This process establishes the procedures and controls for the manufacture of UH-1 windshields of a glass/polycarbonate composite utilizing a polyurethane sheet interlayer.

1.2 Classification. - Two windshield configuration types are considered in this specification and are shown in Figures 1 and 2.



1. Chemcor glass, no. 0401 (0.085 in.)
2. DuPont polyurethane, LRP-366 (0.030 in.)
3. Polycarbonate, Lexan 9030-112 (0.125 in.)

Figure 1 - Type I Windshield Configuration



1. Soda lime annealed plate glass (0.250 in.)
2. Polyvinyl butyral (PVB) adhesive (0.060 in.)
3. Soda lime annealed plate glass (0.125 in.)
4. DuPont polyurethane LRP-366 (0.060 in.)
5. Polycarbonate (0.125 in.)

Figure 2 - Type II Windshield Configuration

1.3 General process description. - E.I. DuPont's LRP-366 polyurethane interlayer in the cured sheet form is completely thermoplastic and is capable of being bonded to particular substrates with proper preparations and the application of heat and pressure. This process describes the procedure in which the thermoplastic characteristic of this interlayer is utilized in the fabrication of UH-1 windshields described in Paragraph 1.2 of this document. The polyurethane resin is mixed as described in Paragraph 3.3.3 of this specification and must be degassed to remove all air from the mix. The liquid resin is poured into flat pans and cured into billets of interlayer stock. These billets can then be wrapped and stored awaiting future processing.

Cleanliness is required because the LRP-366 is tacky and any dirt or foreign material will be difficult to remove.

The interlayer sheet is processed by pressing the billets between heated flat platens causing the LRP-366 to flow under pressure. The press platens are then closed to obtain the desired thickness. The platens are cooled before removal of the finished sheet. This pressed sheet is then ready for processing the UH-1 windshield assembly.

The preformed windshield glass (soda lime or Chemcor) is prepared and primed as described in detail in Paragraph 3.3.2 of this document. The polycarbonate sheet is formed to contour and trimmed to final size. The interlayer sheet is positioned on the glass and the polycarbonate sheet is positioned on the interlayer. A caul sheet is then placed on the inside of the polycarbonate. This sheet acts as a stiffener to prevent ripples from developing in the polycarbonate as the LRP-366 flows under pressure.

The entire assembly is placed in a vacuum bag and subjected to elevated pressure and temperature. The assembly is cooled under pressure until the interlayer is stabilized.

The produced part is then inspected to verify that it is free of air inclusion and the interlayer is of uniform thickness and optically acceptable.

2. APPLICABLE DOCUMENTS

2.1 Government documents. - The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

Specifications

Military

MIL-R-9300	Resin, Epoxy, Low-Pressure Laminating
MIL-C-9084	Fabrics, Woven, Glass, Finished for Plastic Laminate

Standards

Federal

TT-N-95	Naphtha-Aliphatic
Test Method Standard No. 406, Method 3022	Plastics: Method of Testing

2.2 Non-government documents. - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated the issue in effect on date of invitation for bids or request for proposal shall apply.

Goodyear Aerospace

Code 706 Process Standard	Abrasion Resistant Coating

3. REQUIREMENTS

3.1 Equipment. - Required equipment is as follows:

a. Autoclave - Capable of 300 deg F and 220 psi pressure; with pressure and temperature controllers and recorders

b. Hydraulic press - 100-ton capacity and temperature to 260 deg F

c. Oven - Capable of 325 deg F with temperature controls and recorder

d. Oven - Glass forming, capable of 1200 deg F with temperature controls and recorder

e. Degassing equipment capable of drawing vacuum to 50 microns or less.

3.2 Materials. -

3.2.1 Glass. -

3.2.1.1 Chemcor No. 0401, 0.085-in.-thick Corning Glass Works, 80 Houghton Street, Corning, NY 14830. - Chemcor requirements are as follows:

a. Optical quality shall be such that there shall be no bulls eyes, local distortions, or severe banding at low view angles

b. Purchase trimmed to size, and formed to contour per supplied master, 204-030-666-43 or -44

c. All edges will be seamed and free of cracks, chips, or blemishes.

3.2.1.2 Soda lime annealed plate glass. - Requirements for this glass are:

a. Glass shall be free from inclusions, scratches, distortions, and banding at low view angles

b. Plate glass shall be seamed and ground with no chips or scratches.

3.2.2 Polyvinyl butyral adhesive. - This material shall be XA clear, undusted Saflex (PVB) made by Monsanto Chemical Company, 1401 Dove Street, Newport Beach, CA 92660.

a. Rolls shall be sealed and stored at 0 deg F

b. The rolls shall be supported on pipe or bar through the core of the roll and supported on a trunion.

3.2.3 Polycarbonate sheet. - General Electric Company's Lexan 9030-112 shall be the polycarbonate material required. The Lexan extruded sheet must be press polished to remove extrusion marks.

Polycarbonate sheet press polished or as-extruded shall be stored in the original packing case with protective cover in place until material is to be used. If material is removed from the case it shall be stored in a vertical position.

3.2.4 LRP-366 polyurethane. - LRP-366 is composed of the following raw materials:

a. Teracol 1000 resin (E.I., DuPont Company, Chemical & Dye Division, Brandywine Building, B-15243, Wilmington, DE 19898)

b. 1.4 Butanediol (GAF Corporation, Chemical Division, La Habra, CA)

c. Cyclohexane dimenthanol (Eastman Chemical Company, Kingsport, TE)

d. Tinuvin 328 ultraviolet stabilizer (CIBA-Geigy Corporation)

e. Irganox 1010, antioxidant (CIBA-Geigy Corporation)

f. Hylene W, diisocyanate (E.I. DuPont Company, Chemical & Dye Division).

3.2.5 Fiberglass woven fabric. - This material shall conform to MIL-C-9084, and shall be equivalent to Style 181 Volan "A" and Style 128 Volan "A".

3.2.6 Primer. - The primer used shall be A-1100 organo silane ester, manufactured by Union Carbide Corporation, Chemicals and Plastics, New York, NY 10019.

3.2.7 Epoxy resin Epon 828. - Manufactured by Shell Chemical Company, this material shall conform to MIL-R-9300.

3.2.8 Epoxy curing agent. - RF 82/82S is manufactured by Resin Formulators, 8500 Steller Drive, Culver City, CA 90230.

3.2.9 Silicone adhesive. - RTV-102 adhesive sealant is a product of General Electric Company, Silicone Products Department, Waterford, NY 12188.

3.2.10 Abrasion-resistant coating. - This coating (Goodyear Code 706) is manufactured by Goodyear Aerospace Corporation, Litchfield Park, AZ 85340.

3.2.11 Miscellaneous materials. - The following materials shall be used in the process but are not a part of the final product:

a. Bleeder fabric - HE-66 or equivalent, commercial

b. Separator sheets - TFE glass fabrics manufactured by Taconic Plastics, Inc., Petersburg, NY 12138

c. Nylon film, HS-1871 - manufactured by Rico Plastics Inc., San Diego, CA 92110

d. Alconox detergent - manufactured by Alconox Inc., New York, NY 10003.

3.3 Required fabrication procedures. -

3.3.1 LRP-366 preparation. - LRP-366 polyurethane sheet stock shall be processed as follows.

3.3.1.1 LRP-366 premix. - Prepare premix using the following materials:

Teracol 1000	88.9 parts by weight (PBW)
1.4 Butanediol	4.6 PBW
Cyclohexane dimenthanol	4.9 PBW
Tinuvin 328	1.5 PBW
Irganox 1010	0.2 PBW .

Heat above mixture to 210 ±10 deg F and mix continuously until Tinuvin 328 and Irganox 1010 are completely dissolved and blended into resin mixture. Degas under vacuum to 50 microns or less. Premix may be stored in closed containers at normal room temperatures for 60 days.

3.3.1.2 Billet preparation. - Prepare billets as follows:

a. Mix the following materials:

LRP-366 premix	69.2 PBW
Hylene W	30.8 PBW
3 percent UL-28 tin catalyst	1 drop per 100 grams

Note: Mix approximately 2700 grams for 0.060-in. thickness (40-in. × 40-in. sheet) or mix approximately 2000 grams for 0.030-in. thickness (40-in. × 40-in. sheet).

b. Heat LRP-366 premix to 180 ±10 deg F and degas to 50 microns vacuum or below

c. Cool to 145 deg F and add Hylene W and catalyst

d. Degas again to 50 microns or less

e. Pour into pan approximately 15 in. × 30 in. with edges at least 1/4-in. deep and cure 16 hours at 190 ±10 deg F

f. Billets shall be stored protected from contamination.

3.3.1.3 Pressing sheet interlayer stock. - The following procedure shall be used:

a. Preheat plates to 250 to 260 deg F

b. Position billet in center of sheet with 5-mil TFE glass fabric sheet above and below for separation

c. Close press and apply pressure; 50 psi minimum

d. When press has closed to stops (set for thickness required), cool to 120 deg F or less and open press

e. Allow sheets to remain flat between the TFE glass separator sheets until they reach room temperature. If the TFE sheets are then removed, plastic film shall be required to protect the interlayer sheet and to act as a separator between sheets.

3.3.2 Glass preparation. - The soda lime plate shall be cut to size and edges seamed and ground. There shall be no evidence of chips or scratches.

Note: Soda lime glass must be to final size prior to PVB bonding. If ground after bonding, some chips may remain to cause cracks if plate is stressed.

Soda lime glass plies will be twin-formed and maintained as a unit for bonding.

The two pieces of glass shall be checked for contour mismatch. Mismatched glass will cause breakage at the pressures required for bonding.

3.3.3 Polyvinyl butyral bonding. - Polyvinyl butyral bonding of soda lime glass panels shall be performed as follows:

a. Thoroughly clean all glass surfaces as follows:

   (a) Wash with isopropyl alcohol and wipe dry

   (b) Wash thoroughly with Alconox detergent

   (c) Wash repeatedly with distilled water until all traces of detergent are removed and wipe dry.

Note: It is suggested that a water break test or equivalent checking method be made to determine cleanliness of the glass.

b. Remove PVB from roll and allow to stabilize at room temperature. Position the required number of PVB plies on inner surface of the 1/4-in. glass and position the inner ply of glass. Trim PVB to the edge of the glass. Place a thermocouple in the interlayer near the edge of the glass

c. Wrap the edges of the assembly with a suitable bleeder

d. Bag the entire assembly with HS-8171 nylon film and apply vacuum

e. Check vacuum bag for leaks

f. Cure assembly in the following manner:

   (a) Load autoclave and connect vacuum and thermocouple

   (b) Set temperature on autoclave at 275 deg F. When the part temperature reaches 250 deg F, raise pressure to 200 to 210 psi. Hold pressure and temperature for 2 hours after part reaches 275 ±5 deg F

(c) Shut off heat. Hold pressure and vacuum until part temperature drops to 140 deg F or less.

3.3.4 Polycarbonate panel fabrication. - Fabricate General Electric Lexan 9030-112 press polished panels as follows:

a. Remove protective paper from sheet and inspect

b. Clean polycarbonate sheet per Paragraph 3.3.3.a. and apply abrasion coating on one side per GAC Code 706

c. Hang polycarbonate sheet and select the best optical area. Position work template and outline with black crayon

d. Cover uncoated side of sheet with protective paper

e. Place papered surface against saw table and saw to crayon line

Note: Polycarbonate must be handled very carefully to avoid scratching. If polycarbonate blanks are to be stored, they shall be protected. Do not tape to abrasion coated surface.

f. Position polycarbonate in a female mold for forming. The temperature time cycle shall be such that polycarbonate will attain complete contact with the mold, and markoff is not transmitted to the blank. The cooling rate must be such that the part maintains contour.

3.3.5 Bonding procedure with LRP-366 polyurethane sheet interlayer. - Note: The process outlined herein shall be the same whether the assembly is Type I or Type II.

a. Clean mating surface of the glass and polycarbonate panel in accordance with Paragraph 3.3.3.a.

b. Mix silane primer and apply to glass surfaces to be bonded as follows:

(a) Mix primer

45 grams isopropyl alcohol

5 grams distilled water

0.5 gram A-1100 organo silane

(Note: Mix fresh primer for each use.)

(b) Apply to glass by wiping with folded K-dry or equivalent

(c) Immediately buff with dry K-drys until all traces of silane mix are gone and no visible trace of primer is present

c. Select interlayer sheet and remove protective film from one side. Material will exhibit a degree of tack and care must be used to remove separator without distorting sheet stock

d. The exposed interlayer is positioned on the glass and wiped to remove as much trapped air as possible. Then, peel protective film from top surface of the interlayer sheet. Position polycarbonate panel by aligning with the edge of glass, then press the polycarbonate down in a manner that minimizes air entrapment

e. Position fiberglas reinforced plastic caul sheet on the inner surface of the assembly

f. Secure with pressure-sensitive tape to prevent slippage. Wrap entire assembly with H6-66 bleeder cloth or equivalent. Envelope with bag made of HS-8171, 3-mil nylon film. Connect thermocouple in edge of sample, mount vacuum fitting, and seal bag with vacuum seal tape. Check for vacuum leaks

g. Autoclave cure using the following cycle:

(a) Load into autoclave, connect to autoclave vacuum source, and draw vacuum

(b) Connect thermocouple to recorder or readout

(c) Raise temperature of autoclave until part temperature is 225 ±5 deg F. Then raise autoclave pressure to 100 psi in 25 psi increments. Allow 10 minutes at each pressure level. Hold pressure 100 ±5 psi for three hours minimum

(d) Shut off heat and allow to cool under pressure until part temperature is below 140 deg F

h. Remove from bag and clean part.

3.3.6 Edge attachment fabrication. - Edge attachment fabrication shall be performed as follows.

The Type I assembly edge attachments shall be fabricated using four plies of Style 128 Volan "A" fiberglass fabric (both inside and outside pieces).

The Type II assembly edge attachments shall be composed of five plies of Style 181 Volan "A" fiberglass fabric both inside and outside.

Typical layup procedure shall be as follows:

a. Mix 100 PBW of resin Epon 828 and 60 PBW of RF82/82S. RF82/82S is blended 60 PBW of RF82 to 40 PBW of RF82S

b. Apply separator RAM 225 or equivalent. Buff surface thoroughly

c. Impregnate fabric and ply up as required

d. Bag with 3-mil PVA film or equivalent and draw vacuum

e. Paddle to remove excess air and resin

f. Cure for 4 hours minimum at room temperature plus 2 hours at 200 deg F

g. Trim as required.

3.3.7 Assembly of edge attachments for Type I construction. - The procedure for bonding edge attachments for this construction shall be as follows:

a. Position inner edge attachment and apply masking tape to protect inner surface of windshield assembly

b. Sand mating surfaces of windshield assembly and edge attachment where bonding is to be accomplished and wipe with isopropyl alcohol

c. Coat both surfaces to be bonded with General Electric silicone adhesive sealant RTV 102 and clamp together using light pressure. Strips shall be used under clamps to distribute pressure and avoid uneven bond lines

d. Cure at room temperature 24 hours minimum

e. Remove clamps and proceed to bond outer edge attachment laminate in the same manner as described above.

3.3.8 Assembly of edge attachments for Type II construction. - The procedure for bonding Type II construction edge attachments shall be as follows:

a. Position outer edge attachment to outer surface of windshield assembly and tape glass along edge of FRP edge attachment to protect nonbonded area

b. Sand mating surface of edge attachment to roughen surface and remove glaze

c. Apply uniform coat of RTV-102 adhesive sealant to mating surfaces of glass and FRP edge attachment

d. Mate edge attachment to glass and clamp with spring clamps using thin strips to distribute load and maintain a uniform bond line

e. Cure 24 hours minimum at room temperature before removing clamps

f. Remove clamps and prepare FRP strips for inner portion of edge attachment

g. Mark along trim of edge attachment on polycarbonate and remove all abrasion coating by sanding. Wipe with isopropyl alcohol

h. Apply even coat of RTV-102 adhesive sealant to mating surface of windshield and FRP edge attachment laminate

i. Mate edge attachment strips to windshield assembly and clamp with spring clamps using thin strips to distribute load and maintain a uniform bond line

j. Cure 24 hours minimum at room temperature with clamps in place

k. Remove clamps, clean, and trim to required dimensions.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. - Unless otherwise specified in the contract or order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the government. Where applicable the government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Equipment monitoring. - Quality Assurance personnel shall monitor cure records.

Inspection and operating personnel shall verify that the calibration check of test instruments and recording instruments has been made within the required period.

4.3 Material monitoring. - Quality Assurance personnel shall ensure that materials used in the fabrication of Type I or Type II panels are in accordance with the applicable requirements.

4.4 Certification. - Not applicable.

4.5 Test methods. -

4.5.1 Classification of tests. - All tests or evaluation processes described herein shall be classified as acceptance testing.

4.5.2 Examination. - Assemblies shall be examined for compliance with requirements for construction, finish, and workmanship.

4.5.3 Light transmission and haze. - Determination of light transmission and haze shall be made on each assembly. Testing shall be in compliance with Method 3022 of Federal Test Standard 406. The specified limits shall be established by the procuring activity, or as specified on engineering drawings.

4.5.4 Optical deviation. - Optical deviation shall be measured by the use of a 15- to 20-power telescope mounted on a stand of sufficient rigidity to maintain alignment. The telescope shall be aimed such that its self-contained crosshairs are aligned on an annular target mounted at a specified distance. The annular rings shall be of a radius equal to the tangent of the number of minutes of arc times the distance between telescope and target. The target shall be marked in minutes of arc from 1 to 15. The test article shall be viewed normal to the line of sight of the telescope. The allowable deviation shall be as specified by the procuring activity or by the engineering drawings.

4.5.5 Optical distortion. - The optical distortion of each assembly shall be determined by viewing a grid board through the assembly. A visual examination of the article may be made by viewing the grid board through the test assembly; a physical measurement of a line distortion can be made by photographing the grid board through the assembly.

The specific test procedure and frequency of test shall be established by the procuring activity. The distortion limits for the subject assembly shall be as specified on the engineering drawings or as specified by the procuring activity.

5. PREPARATION FOR DELIVERY

Not applicable.

6. NOTES

6.1 Intended use. - This specification covers the requirements for fabricating composite UH-1 windshields utilizing a specific interlayer.

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